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HEARINGS

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

SECOND SESSION

ON

MARCH 9, 1990
NASA OVERVIEW

MARCH 28, 1990
SPACE SHUTTLE/SPACE STATION

APRIL 3, 1990
MISSION TO PLANET EARTH

MAY 3, 1990
AERONAUTICS AND SPACE TECHNOLOGY

MAY 10, 1990
SPACE SCIENCE AND APPLICATIONS

MAY 15 1990
COMMERCIAL SPACE PROGRAMS

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NASA OVERVIEW

FRIDAY, MARCH 9, 1990

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met pursuant to notice at 9:38 a.m. in room SR-253, Russell Senate Office Building, Hon. Albert Gore, Jr. (chairman of the subcommittee) presiding.

Staff members assigned to these hearings: Steve Palmer, senior professional staff member; and Louis Whitsett, minority staff counsel.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. The subcommittee will come to order.

I want to welcome our witnesses and guests. We are starting a few minutes late because the Senate was in session until well after midnight last night, and those of us who have been fighting various battles on the Clean Air Act were working well into the wee hours of the morning. So that is the reason for the few minutes delay in our starting time this morning.

Today the Subcommittee on Science, Technology, and Space will initiate its review of the fiscal year 1991 NASA budget request. As everyone is well aware, the budget request for fiscal year 1991 is $15.1 billion, 23 percent higher than the current fiscal year 1990 operating plan.

The projected budget for fiscal years 1992 to 1994 also reflects annual increases in the range of 20 to 25 percent—a Herculean challenge during these times of fiscal austerity. It is important, therefore, that the committee have an in-depth understanding of the NASA budget request, so that it can help make the case for the substantial budget increases contained in this request.

The subcommittee is very pleased to welcome Admiral Truly, J.R. Thompson, and Tom Campbell, who I understand are well prepared to defend the President's budget request and to give this committee a better appreciation for the President's support of this budget and the proposed mix of new and old programs.

Today will be the first of several hearings intended to get a dialogue going between NASA and the committee. Today we will start our review of the budget. But we will also explore certain themes and macroeconomic issues with you that are important to the Congressional budget process as we deal with it from the vantage point of this committee.

As you are well aware from our previous discussions, I think it is awfully important that we have a better appreciation as to how this budget request will do several things: make America more competitive, for example; ensure the development of critical technologies; and attract our nation's youth to science, engineering, and mathematics.

I also think it is important for the committee to understand how the Administration intends to fund the ongoing program, as well as the two new initiatives included in this request for the Earth Observing System and the Human Exploration Initiative.

As you already know, I personally believe that the EOS program, which is part of the Mission to Planet Earth, is the most important new start to come before this committee in quite some time. I have been engaged in a review of exactly how this program is being structured and I and others will have some suggestions on ways the initiative can be improved in our view.

But overall, of course, this committee is strongly supportive, and I personally wish to say that I am strongly supportive of Mission to Planet Earth. I have argued for it for a long time and I think that EOS is a critical part of it.

I do believe that we can make much better use of existing data, information already collected but not yet analyzed or used effectively. We have had some discussions about this particular aspect of the program and I am encouraged by the level of attention being given by NASA to this issue at the onset of the program.

The program is relevant not only to a present political policy, science problem; it is also a classic case of how space technology can be made to work for the benefit of all humankind.

I realize we have a lot of issues to discuss this morning, but before I yield to my distinguished colleague, Senator Kasten, I want to make one other comment. Today's NASA budget oversight hearing is the last NASA hearing in which this subcommittee and this committee will have the services and undivided attention of Marty Kress.

I have sometimes been present in hearing rooms when a committee staff director departed from the committee and made his transition to another job, and have heard the accolades. I will tell you, I have never been present when accolades were more deserved than they are for Marty Kress.

We feel fortunate that Steve Palmer is coming on to fill his very big shoes, and we will look forward to working with Steve Palmer. We also feel fortunate that Marty is going to be downtown with NASA and will continue to have a working relationship with this committee.

But I want to say, in behalf of all of my colleagues and all the other staff members here and all who have had a chance to work with Marty, that we really deeply appreciate his service and his outstanding professional work.

Now let me recognize Senator Kasten.

OPENING STATEMENT BY SENATOR KASTEN

Senator Kasten. Mr. Chairman, thank you.

First of all, let me associate myself with your remarks on Mr. Kress. But most of the people that we have heard going downtown tripled or quadrupled their salaries. That did not work out quite the way some people might have planned it.

But Mr. Chairman, I am happy that we have got Administrator Truly and Mr. Campbell before us to provide this overview of the NASA budget as we continue in an environment of tight budgets and tight resources and Gramm-Rudman and whatever. NASA is an agency that has suffered tremendously over the recent past.

The direction over the next decade and beyond depends in large measure on the investments and the amount of the investments that we make this year, that we make now. I am pleased that the Administration's request does represent a significant increase, 23, 24 percent over last year, coming to a total of $15.1 billion.

Most importantly, the support for Mission to Planet Earth is supported in this budget in the amount of $686 million. This 15-year, $30 billion program will use our space and other technology to better understand this planet and the changes that are or could be occurring over the near term and beyond, and I believe that, at least on this committee, you have strong bipartisan support for certainly the thrust of that program, if not all of the details.

President Bush's next generation manned program, the Human Exploration Initiative, is also to receive $225 million. This is the first phase, the initial phase, of a program that will ultimately have a cost exceeding $500 billion and return us to the Moon, on to Mars and beyond.

Mr. Chairman, the outgrowth from the Space Station research, the programs just mentioned, and the other programs in transportation, materials, and other areas benefit this nation as it tries to maintain its technological lead. These are the areas in which we are turning our pure research into practical technology, and I think this translates into jobs and I think it translates into competitiveness for the United States of America as we look out to Europe 1992, the emergence of a united Germany, and a growing economic power in Japan, Korea, and other places in Southeast Asia.

It is my hope that we can see more of our research in NASA's arena redound to the benefit of U.S. companies who are picking up the commercial applications and taking and using them to strengthen our economy.

So Mr. Chairman, I look forward to today's hearing and I hope we can continue to work with and support the efforts of NASA.

Senator GORE. Thank you very much, Senator Kasten.

I have a statement that Senator Hollings would like to have included in the record.

[The statement follows:]

OPENING STATEMENT BY THE CHAIRMAN

During the course of the last year, I had the privilege of participating in two of the most inspiring political events of my political career—the addresses to Joint Sessions of Congress by Lech Walesa and Vaclac Havel. Who, in this day and age, ever would have thought that these men could play such an important role in reshaping the political map of the world? Who among us ever believed that the dream of democratic government in Eastern Europe could become a reality in our lifetime?

I mention these events today because I believe that Lech Walesa and Vaclac Havel have played a significant role in reminding us how important our dreams are. In space, our dreams can include believing that we can conquer space and that permanently manned laboratories and Moon bases are achievable in our lifetime. Nations, just like individuals, need to be able to dream, and they need to be able to turn some of their dreams into realities. Nations, just like individuals, need challenges. Our reach should far exceed our grasp, or we will not progress.

Today, Admiral Truly, you have the difficult challenge of trying to convince an institution to dream when it has grown old, tired and cynical as a result of a decade-long budget battle. You, Admiral Truly, have the challenge of trying to get funding for new initiatives when the Congress is having problems funding existing initatives. You have the challenge of proposing increases when such increases can come only at the expense of other programs—dreams confronted by realities.

Nevertheless, Admiral Truly, hopefully you and the Administration can join us in our pursuit of a decade of the nineties that is a decade of opportunities and challenges, an era when dreams can become realities, and the period when we finally resolved the budget problem. Hopefully, the decade of the nineties will be a time when we pursue space challenges and when your dreams about space can become realities rather than being impeded by realities.

Admiral Truly, I look forward to your testimony, and I look forward to working with you to shape the space program of the nineties and the twenty-first century. A wise man, and good friend of mine, Dr. Benjamin Mays, once said:

"The tragedy of life doesn't lie in not reaching your goal. The tragedy lies in having no goal to reach. It is not a disgrace to reach for the stars, but it is a disgrace to have no stars to reach for."

That is good advice for us all.

Senator GORE. Admiral Truly, I have said on many occasions how greatly I respect you personally and your leadership at NASA. We have a habit of repeating things like that up here in the Senate. They are heartfelt in spite of the fact that you have heard it before.

We are really glad to have you and J.R., a long time friend, and Mr. Campbell to appear before us this morning, and we invite you to proceed as you see fit.

STATEMENT OF ADMIRAL RICHARD H. TRULY, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY JAMES R. THOMPSON, DEPUTY ADMINISTRATOR; AND THOMAS CAMPBELL, COMPTROLLER

Admiral TRULY. Thank you, Mr. Chairman.

With your permission, I would like to submit for the record my written statement, but I would like to take a few moments and outline for you my views of this year's President's request of our budget.

Senator GORE. As always, we will put your full written statement in the record and be glad to hear from you.

Admiral TRULY. Thank you, Mr. Chairman.

I really do welcome the opportunity to present the President's fiscal year 1991 budget to this committee in this particular hearing. It outlines, I think, a future direction of America's civil space and aeronautics program which is very exciting. And as I sit here today, I can tell you that these days in America's space program are exciting days.

I just talked to Bob Crippen, who is Director of our Space Shuttle program. Tomorrow the Space Shuttle Atlantis will be ferried back from Dryden Flight Research Facility out at Edwards, back to the Cape for its next flight. And next week the next shuttle will be rolled out to the pad for the long-awaited and exciting Hubble Space Telescope mission.

We have just concluded an outstanding year, one of the best years in NASA's history. We have completed a total of nine superbly successful shuttle missions and essentially on schedule as we had predicted a couple or three years ago. The program is going extremely well and is delivering what I would describe as world-class performance.

Also, we in the past year have terminated a twelve-year hiatus in our planetary programs, with sophisticated spacecraft heading for Venus and for Jupiter. Also, last year, after twelve years of innovation and ingenuity by a control team at the NASA Jet Propulsion Laboratory, scientists and engineers and technicians mothered the Voyager 2 spacecraft as it had its encounter with the Planet Neptune some 12.3 billions of miles from Earth.

President Bush is committed to a sustained, continuing and balanced program that advances U.S. leadership in aeronautics and space. The budget recognizes and acknowledges that NASA's activities embody highly significant contributions to building a better America.

Our programs are about expanding knowledge of our Earth and of our universe, of protecting and understanding our fragile environment, of enhancing U.S. economic competitiveness, and also contributing in a very real but intangible way to the national pride of our people.

Finally, I would say that one of the things that I am most proud about NASA's programs is that they provide a strong stimulus to young people, to kids. Their interest in science and engineering drives them to education, particularly where we need it the most, I think, and that is interesting young people in mathematics and science education in our country.

Our mission embodies three major areas of endeavor, which are science, technology, and exploration, and I would like to touch briefly on all three.

First, innovative science. We literally are in a new golden age of space science, with 36 major missions planned over the next five years. We are returning to the planets with Magellan and Galileo, Mars Observer, and CRAF/Cassini. From now until well into the next century, there will be an uninterrupted sequence of U.S. planetary missions in their primary phase of exploration.

Before the end of this century, we will have three great observatories, first led by the Hubble Space Telescope, in orbit. Certainly these are exciting times.

Science is also served in NASA well by the men and women of the Space Shuttle program, as it will be later in this very decade about Space Station Freedom. Microgravity research and materials and life sciences is enhancing our fundamental understanding and will lay the groundwork for future programs and also for future commercial activity here on Earth.

A critical element in this year's budget and our science program is Mission to Planet Earth, NASA's major contribution to the U.S. global change program. This budget initiates the Earth Observing System as a major part of our activities. Through the EOS and the other Earth probes that are part of Mission to Planet Earth, we have already studied the other planets and through EOS we will study our own planet in great detail: the land, the sea, the ice, the atmosphere, and the people and the way we affect our very planet.

This must be done from space. There is no other way to get the global information and data set so that we can build the models that will allow us to first understand our Earth and then face up to the decisions that must be made.

Next I would like to briefly touch about competitive technology and how NASA contributes to it. NASA has been a preeminent force in the development of America's advanced technology over the past 30 years. This budget request contains investments in cutting edge aeronautics and cutting edge space technologies which will enhance U.S. competitiveness abroad and our economic wellbeing at home.

Aeronautics in the United States is unique for its contribution to balance of trade, to the transportation infrastructure, not just for America but for world commerce and to our national security. NASA, as our country's focal point for aeronautical research and technology, will continue to address these issues to maintain the U.S. competitive posture in aviation.

Emphasis in aeronautics in NASA is being placed on numerical simulation techniques, including massively parallel computers, to do aircraft design and propulsion system design and the understanding of aerodynamics critical to more efficient flight.

NASA will continue to support the Federal Aviation Administration in addressing issues such as congestion, aerospace safety, and aging aircraft through our research. The high-speed research program at NASA will address the critical environmental issues—those are sonic boom amelioration and also propulsion constituents so that we do not destroy the upper ozone layer—with a program that we call the high-speed civil transport program, which is pointed at studies that show a large market in the early part of the next century.

Our joint effort with the Department of Defense on the National Aero-Space Plane spans the full spectrum of technology development. This program will lead to a whole new generation of vehicles, to U.S. preeminence in high-speed aeronautics, and to rapid, flexible, and efficient access to space.

Investment in space technologies is essential to maintaining our capabilities. Throughout all of these efforts, we seek new, innovative concepts. We are going to be working on automation, on robotics, on propulsion systems, on power, on information technology, and large structures and controls.

Thirdly after science and country and competitiveness, I would like to talk briefly about bold new explorations. I have already talked about explorations that we have under way today to the outer planets and our robotic program. On July 20th of last year, President Bush provided a focus that I believe will guide this nation's efforts for decades, literally well into the twenty-first century.

His Moon/Mars initiative directs us to complete Space Station Freedom in the 1990's, then in the twenty-first century to return to the Moon, this time to stay, and then to venture on later to the planet Mars. It is with this budget that we will begin mankind's last historic journey.

We will be living and working permanently in space well before the end of this decade, about Space Station Freedom. We will be undertaking space exploration with our return to the Moon and the journey to the planet Mars.

We are going to be casting our nets very widely across America to capture America's creative energies. We intend the broadest possible and innovative involvement of U.S. industry, universities, and other Federal agencies and research facilities.

At the same time, we will start and continue our mission concept and architecture studies, systems analysis, heavily looking at science payoffs from such missions and technology development efforts.

Our early activities will be very modest and a very small amount of money is in the fiscal year 1991 budget, but it is for new, innovative technologies that have an opportunity to reduce the schedules, the cost, the risk, and increase the performance of such a massive undertaking.

The Moon/Mars initiative will include robotic science missions, as well as manned missions, as an integral part. And this budget requests an enhancement for the Mars Observer flight to fly in 1992 and also preliminary work to start a Lunar Observer and the Lifesat missions.

Underlying those objectives of science, of technology and exploration are all the mechanics of what builds a NASA budget, and I can tell you today that those mechanics are better balanced in this budget than any budget NASA has brought before the Congress, in transportation, in facilities, in people, in all those things that it takes to run this very complicated and important agency.

Mr. Chairman, this proposed budget I believe is unique for several reasons. First of all, it is formulated on the basis of world class performance of a series of highly successful Space Shuttle, space science, and expendable launch vehicles missions that we have achieved through the private sector.

With the transition to fabrication of Space Station Freedom, the initiation of an ambitious effort in Mission to Planet Earth, and the undertaking of a technology program to enable human exploration, the NASA program has assumed a broader and more complex dimension. As a result, we find ourselves on the boundaries of new frontiers.

First is the frontier of scientific understanding of our universe, our solar system, and our own planet. Another is the frontier of technology for the next century, the ability to do those things reliably, safely, and economically that our nation demands. And finally, the frontier of the human spirit, which will be crossed when humans are able to live and work in the next century on other planets.

I want to reemphasize that the dominant portion of this request, fully 98 percent of this request, is to support programs that we have debated with you in the Congress over past years. It is to support the ongoing program. But the two new initiatives in global change and human exploration, even though relatively small, particularly in the exploration program, are most important for the future.

Our total program is enabled by the resources that are represented in this budget and are an investment in America's future. I seek your support, Mr. Chairman, and those of your colleagues and this committee and in the Congress to supporting us in what I believe is a very forward-looking, future-oriented, important and complex NASA request for fiscal year 1991.

And we would be pleased to answer any of your questions this morning.

[The statement and questions and answers follow:]

Statement of

Richard H. Truly
Administrator

National Aeronautics and Space Administration

before the

Subcommittee on Science, Technology and Space

Committee on Commerce, Science and Transportation

United States Senate

Mr. Chairman and Distinguished Members of the Subcommittee:

I welcome this opportunity to present the President's FY 1991 budget request for the National Aeronautics and Space Administration, and to discuss the future direction of our Nation's civil space and aeronautics program which this budget represents. We have just concluded a year in which NASA maintained its role as a principal symbol of American technological and scientific prowess. An improved and more reliable Space Shuttle fleet was employed in a demanding series of missions, and a 12-year hiatus in planetary launches ended, as sophisticated spacecraft were launched on journeys to Venus and Jupiter. At the same time, 12 years of innovation and ingenuity by a control team of NASA scientists, engineers and technicians culminated in Voyager 2's encounter with the planet Neptune, an event that captivated a world audience.

President Bush is committed to a sustained, continuing and balanced program which advances U.S. leadership in aeronautics and space. The President's FY 1991 budget request for NASA of $15.1 billion in discretionary authority provides the resources necessary to maintain us on a steady course toward achievement of that goal.

The President's budget request acknowledges that NASA's activities embody highly significant contributions to our efforts toward building a better America. Our programs are aimed at building mankind's store of knowledge about our planet and our universe, at helping to understand and to protect our fragile environment, at enhancing U.S. economic competitiveness, and contributing to an intangible but critical national pride in ourselves and our accomplishments as a Nation.

One of the most valuable contributions of the U.S. space program is that it provides a strong stimulus to young students' interest in science, engineering and mathematics education. This budget, in fact, enhances specific NASA efforts aimed at using space endeavors in classrooms around the country to help in assuring American preeminence in math and science education by the end of the century. In addition, NASA's extensive international cooperative activities in programs like Space Station Freedom and Mission to Planet Earth allow our efforts to serve U.S. foreign policy, as well as domestic policy, goals. NASA is a vital part of the American infrastructure. Investment in civilian space research and technology has contributed to America's infrastructure of today and will serve as a foundation for America's infrastructure of tomorrow.

SCIENCE, TECHNOLOGY AND EXPLORATION

NASA's mission embodies three major areas of endeavor: science, technology, and exploration. Our undertakings in these areas have intrinsic merit while, at the same time, serving broad national objectives. I would like to describe briefly some of our activities in these areas and attempt to place those activities in a broader national context. You will be receiving more detailed testimony on all our programs over the coming weeks.

Innovative Science

In space science, we are expanding our base of knowledge with benefits both foreseen and unforeseen. We have entered a "golden age of space science" with 36 major missions planned over the next five years. We are returning to the planets with Magellan, Galileo, Mars Observer, and CRAF/Cassini. We have emerged from a period of more than a decade of virtually no activity. From now until well into the next century, there will be an uninterrupted sequence of U.S. planetary missions in their primary phase of exploration. Before the end of the century, we will have launched three Great Observatories, starting with Hubble Space Telescope this spring. These are exciting times--our understanding of the universe will soon increase manyfold. In addition to our robotic programs, science is also served by men and women aboard the Space Shuttle, as it will be in the future on Space Station Freedom. Microgravity research in materials and life sciences is enhancing our fundamental understanding of materials processing and life functions. This fundamental understanding will lay the groundwork for future manned activity in space and also for future commercial activity on the ground.

A critical element in our science program is Mission to Planet Earth, NASA's major contribution to the U.S. Global Change Research Program. This budget request initiates the Earth Observing System as a major part of our activities in service of the global environment. We will monitor the Earth, tracking environmental changes over many years. Just as we study the other planets, we will study our own--looking at the complex interactions among the land, the sea, the ice, and the atmosphere. We must understand carbon dioxide build-up, ozone depletion, deforestation, and desertification as an essential element of intelligent action. We will do our part to improve this planet for our children and our grandchildren.

Competitive Technology

NASA has been a preeminent force in the development of America's advanced technology over the past 30 years. We develop technology to do our space flight programs and to develop a base to support our national leadership in aeronautics. This budget request contains investments in cutting-edge aeronautics and space technologies which will enhance U.S. competitiveness abroad and economic well-being at home. These efforts also support U.S. industry's interests in space commercialization.

Aeronautics in the United States is unique in its contribution to the balance of trade, to the transportation infrastructure for world commerce, and to our national security. It is also a symbol of U.S. technological might. NASA, as our country's focal point for aeronautical research and technology, will continue to address these critical issues with high-leverage technologies--advancing at a rate unmatched since the 1950's--in order to maintain and strengthen the U.S. competitive posture in aviation.

NASA continues to lead the development of the aeronautics technology base that is critical to the design of all future advanced aeronautical systems. Emphasis is being placed on numerical simulation techniques, including new, massively parallel computers, which will lead to further advances in the design of aircraft and propulsion systems and to the understanding of aerodynamics critical to more efficient flight. NASA will continue to develop long-term technology solutions to support the Federal Aviation Administration in addressing issues such as congestion, airspace safety, and aging aircraft. Advanced composite materials and structures research efforts will be increased to exploit new, higher temperature organic composite materials that will significantly lower the weight and cost of high-speed aircraft. The High-Speed Research program will address the critical environmental issues associated with high speed civil transports, providing the foundation for future decisions on technological and aircraft development. These aeronautics programs will offer major payoffs in aircraft performance and capabilities and provide substantial positive impact on U.S. economic competitiveness.

Our joint effort with Department of Defense on the National Aero-space Plane spans the full spectrum of technology development. The results of this program could lead to a whole new generation of vehicles, to U.S. preeminence in high-speed aeronautics, and to rapid, flexible, and efficient access to space.

Investment in space technology is essential to maintaining the Nation's capabilities and to ensuring future U.S. leadership in space. Throughout all our technology development efforts, we seek new, innovative concepts. We will be working on automation and robotics, propulsion, power, information technology, and large structures and control, all of which will enable efficient, reliable access to Earth orbit, enhance operations in Earth orbit, and increase the effectiveness of science missions from Earth orbit. We will also be developing the range of critical technologies needed to expand human presence and activity into the solar system.

Bold New Explorations

On July 20 of last year, the President provided a focus which will guide this Nation's space efforts for decades to come. His Moon-Mars Initiative directs us to complete Space Station Freedom in the 1990's, then, in the 21st century, to return to the Moon, this time to stay, and to venture on to the planet Mars. In so doing, we are addressing one of the most fundamental of human needs--the need to explore and expand horizons. That innate desire fueled the discovery of America, our Westward expansion, and our treks to the Earth's polar regions.

It is with this budget that we will begin mankind's latest historic journey. We will be living and working permanently in space well before the end of this decade. And then we will be undertaking space exploration with our return to the Moon and journey to Mars. We will be casting the nets widely to capture America's creative energies. We will enlist the broadest possible involvement of U.S. industry, universities, and other Federal agencies and research facilities. And, in parallel with this search for new ideas from outside sources, we will continue our own efforts to conduct mission concept and systems analysis studies, science activities, and technology development efforts. These efforts will follow up on last fall's 90-Day Study which established a data base, and which will be one of the points of departure for our upcoming efforts.

Our early activities will focus on technology development with a search for new and innovative approaches--approaches which could have significant impacts on human exploration schedules, cost, risk, and performance. Spurred by this focus on technology development, those efforts will provide early ancillary benefits such as strengthening U.S. capabilities in key industries, stimulating science, engineering and mathematics education, and promoting excellence in science and engineering disciplines. The Moon-Mars Initiative will include robotic science missions as an integral part. This budget request includes a significant enhancement to Mars Observer which is scheduled for a 1992 launch, and final definition studies for two FY 1992 development starts--Lunar Observer and Lifesat. These missions, in addition to significantly advancing scientific knowledge of the Moon and Mars, will obtain data needed to assist in the design and development of subsequent human exploration systems and missions.

ENABLING INVESTMENTS

The high standards and difficult goals we reach for in NASA require investments in our people, facilities, and transportation capabilities to support our missions. The Space Shuttle, Space Station Freedom, Expendable Launch Vehicles, the Tracking and Data Relay Satellite System, and the unique capabilities of NASA's facilities and workforce all form the critical base, without which none of our missions can be achieved.

The Space Shuttle is vital to our space objectives. The program continues to demonstrate its successful return to flight, accomplishing nine remarkable flights since September 1988. The missions have been smooth, and we have stayed extremely close to our target launch dates - particularly on the planetary missions with narrow launch windows. We remain committed to safe and reliable flight operations and will continue to seek ways to increase our margin of safety in what is inherently a risky and unforgiving operational regime. The new manifest recently issued includes eight flights in FY 1990, 10 flights in FY 1991, and 11 flights in FY 1992, as we work toward a flight rate of 12 per year.

In addition to the Space Shuttle, Expendable Launch Vehicles (ELVs) are used to launch NASA spacecraft. These launch services are being procured from the private sector. NASA is committed to encouraging a healthy and expansive commercial space industry. As an example, NASA's nationwide network of 16 Centers for Commercial Development of Space represents a unique example of how Government, industry, and academic institutions can combine resources and talents to develop an industry-driven technology base in order to encourage and foster significant private sector investment and participation in commercial space ventures.

It is also important to continue to invest in measures which enhance the safety, reliability, and performance of the Shuttle system. The Advanced Solid Rocket Motor will incorporate changes in configuration, design details, and materials to meet more stringent design requirements and enhance safety margins and reliability. In addition, we expect a 12,000 pound increase in the delivery capability of the ASRM-equipped Shuttle. Funding is included in this budget request to continue the procurement of structural spares to replace those being used in the building of the new orbiter, Endeavour. The production of these spares will help maintain the capability to produce orbiters and significantly reduce the time to repair a damaged orbiter or build another, should the decision be made to do so. NASA is currently finalizing an agreement with Rockwell for the commercial provision of the hardware necessary to provide an extended duration orbiter capability. The hardware being developed under this program will allow the orbiter to stay in orbit up to 16 days. This capability is targeted to support the flight of USML-1 in FY 1992.

The current Space Shuttle fleet provides a base for our current requirements of transporting people and payloads to low-Earth orbit. A key issue for conducting human exploration missions is how large amounts of cargo can be transported to Earth orbit in the most cost-effective manner possible. Preliminary studies indicate that a significant increase in the lift capability to low-Earth orbit will be required. In the Advanced Launch Systems program, NASA and the Department of Defense have been working closely together on the advanced cost-effective technologies required to meet the future needs of both agencies. NASA also has studies under way, through FY 1990, on the Shuttle-C, an unmanned heavy-lift vehicle derived from Shuttle components. Beginning in FY 1991, NASA will consolidate all of these activities under the Advanced Transportation Technology program. Funding is included in FY 1991 to expand this program to pursue definition activities of heavy-lift vehicle concepts to support Lunar and Mars missions and expand NASA development of a low-cost advanced main engine propulsion system.

Space Station Freedom is the cornerstone of our space program in the 1990's and beyond. It will be a facility for the conduct of research and technology development that is enabled or greatly enhanced by the presence of humans in space. It will contain attachments for the mounting of telescopes and other scientific instruments and it will encourage the development of robotic technologies to aid the crews in maintenance, repair, and replacement. Although the management of the U.S. polar platform has been transferred to the Office of Space Science and Applications, the U.S. polar platform and the European polar platform continue to contribute directly to the Space Station Freedom on-orbit operating concept and remain fully subject to our international agreements with Europe, Japan and Canada. By providing the opportunity to spend long periods of time in space, the Space Station will be a testbed for the development of technologies for human exploration of the Moon and Mars. It could also be evolved into a transportation hub for the exploration of space.

This is a critical time for the Space Station. The program is transitioning from the preliminary design to the fabrication and testing of development hardware. A major review of the program, conducted in the last half of 1989 with U.S. users and our international partners, resulted in a rephasing of the program while preserving the same basic configuration and capabilities. All major contractors are on board, as are many of the subcontractors. The NASA program organization has been strengthened. All are looking forward to continuing the momentum of the effort.

The NASA Ground and Space Communications Networks provide the vital spacecraft operations, tracking, telemetry, command, data acquisition, communications, and data processing to meet the requirements of all NASA flight projects. This is accomplished through the use of a network of NASA ground stations and by three Tracking and Data Relay Satellite (TDRS) spacecraft working with a highly specialized ground station. This budget request continues development funding for a second Tracking and Data Relay Satellite System (TDRSS) ground terminal, additional TDRS spacecraft, and final definition studies of an Advanced TDRSS to extend network service into the 21st century and accommodate the future mission requirements projected for this era.

NASA's unique facilities and technical expertise are the underpinning for the successful accomplishment of the Nation's aeronautics and space programs. We cannot be leaders in space exploration without a first-class institutional capability.

Eighty-five percent of our research and development and operational funding goes to private sector contractors. We must have an in-house workforce that is technically at the forefront to be able to effectively monitor and direct these efforts and understand the details of the technology and science to be accomplished. The FY 1991 budget request contains an increase in the number of civil servants who are urgently needed to meet the increased workload associated with the Earth Observing System program, the Space Station Freedom program, and to enhance the capability of the workforce.

The need for first-class facilities is also key to maintaining our Nation's leadership position. The research laboratories, computing capabilities, aeronautical facilities, Space Shuttle launch facilities, rocket test stands, and deep space tracking stations of NASA are unique national resources. The NASA wind tunnels are used not only by NASA but are also depended on heavily by Department of Defense and the U.S. aerospace industry. They are key to developments in the aerospace industry, making the industry more competitive. The agency is currently in the third year of a five-year revitalization program to modernize NASA's major wind tunnels. This program has been formulated to restore NASA's aeronautical research and development facilities for productive use for the next decade and into the 21st century. The Numerical Aerodynamic Simulator is a preeminent computing capability required to obtain solution of complex aircraft design geometries which are currently intractable. All these facilities must be maintained to protect the huge investment the Nation has made in them. The repair, rehabilitation, and modernization of NASA's facilities is a high priority of the FY 1991 budget request.

SUMMATION

Mr. Chairman, this proposed budget is unique for several reasons. First, the budget has been formulated upon a foundation of a series of highly successful Space Shuttle and space science missions. With the transition to fabrication of Space Station Freedom, the initiation of an ambitious effort in Mission to Planet Earth, and the undertaking of a technology program to enable human exploration beyond Earth orbit, the NASA program has assumed a broader and more complex dimension. As a result, we now find ourselves at the boundaries of three new frontiers. One is the frontier of scientific understanding of our universe, our solar system, and our own planet. Another is the frontier of technology for the next century -- the ability to do reliably, safely, and economically everything that the challenges of space demand. And the third is the frontier of the human spirit which will be crossed when humans are able to live and work on other planets.

The proposed FY 1991 budget demonstrates concretely the President's commitment to provide the resources required to advance these frontiers and to establish a robust American presence in space. While the resources required represent an increase over prior fiscal years, the dominant portion of those resources are needed to support the ongoing program previously approved by the Congress. However, as I have stated, the total program enabled by these resources represents an investment in America for both the near term and for future generations, and, I believe, merits the full dollar investment reflected in the President's request. I seek your support, Mr. Chairman, and the support of this Committee, in obtaining Congressional approval of the $15.1 billion program as outlined in NASA's budget submission.

Mr. Chairman this concludes my prepared remarks. I would be pleased to respond to your questions and those of other Members of the
Subcommittee.

Responses to written questions submitted by Chrm. Gore resulting from the March 9, 1990, hearing.

Question 1: Despite the fact the FY 1991 budget request included funding for the Earth Observing System and the Human Exploration Initiative -- two major new starts -- the Administration has requested independent outside reviews of both of these initiatives. In the case of the Human Exploration Initiative, the review by the National Academy of Sciences was just released and the Aerospace Industries Association review is due next month. In the case of the Earth Observing System and the U.S. Global Change Research Program, the review is being conducted only by the Academy and its findings will be available by April 2. Furthermore, I understand NASA has been instructed to solicit additional outside inputs on the Human Exploration Initiative from the university research community, industry, independent research groups and other federal agencies.

a. In light of all these additional activities, what is the nature of the EOS and Human Exploration Initiative proposals before the Committee? And why should the Committee provide FY 1991 funding if the scope, content, timing etc. of these projects are still under review?

b. To what extent will and could these outside reviews influence the timing, scope and content of these initiatives?

c. What is the exact nature of these outside reviews? Who initiated them? Would you kindly provide the Committee with copies of the letters requesting these studies and the exact terms of reference?

d. How will these outside reviews be factored into the "pending" FY 1991 budget request and who will these reviews be presented to? NASA? OMB? The National Space Council? or OSTP? And then what will happen?

Answer 1a: The funds requested for the Space Exploration Initiative (SEI) in the FY 1991 budget submission are intended to explore mission options and support long lead technology. We need to understand the scope, content, timing, etc. before any decision or proposal is made to proceed. No detailed program plan or schedule has been determined for SEI, although the general direction for proceeding was announced by President Bush last July. We will be completing Space Station Freedom in the 1990s, returning to the Moon with a permanent outpost, and then sending humans to explore the planet Mars. Beyond this initial framework, no decisions have been made on when to go or how to get there. In fact, much work must be done before these decisions can be made. Funding for FY 1991, will allow NASA to begin this essential preliminary work in earnest. Internally, we will be continuing mission studies, focusing on critical technology areas, working on robotic missions such as the Mars Observer and Lunar Observer, ensuring that Space Station Freedom will have the ability to evolve appropriately for SEI needs, and planning for science opportunities on the Moon and Mars. The reviews cited are providing important information on whether we are on the right track in defining the initiative. As you mention, NASA will also be conducting a nationwide outreach program which will solicit and evaluate new and innovative ideas and technologies for SEI from many sources. All of these activities are an attempt to ensure:

1) that we are considering the full range of possibilities and can select how to proceed based on a proper understanding of the technology which is available or can be developed, and 2) that we have done sufficient analysis to thoroughly understand the program scope, content and cost. Without adequate funding in FY 1991, informed program decis[illegible] by the Congress and the Administration will be postponed.

b. At the present time the timing, scope and content of the Space Exploration Initiative (SEI) have yet to be established. Outside reviews, new ideas, and new technologies have the potential to have a significant influence on the program plan which will emerge from our activities over the next few years. In particular, the National Research Council and Aerospace Industries Association reviews will be useful to NASA and the National Space Council as we look together at possible ways to accomplish the President's goals. The outreach program will also influence SEI, as we hope to incorporate into our planning many of the ideas and technologies brought forward during this process.

c. The National Research Council was asked by Vice President Quayle to review NASA's 90-day study report; their report, Human Exploration of Space, was sent to the National Space Council in late February. The Vice President also sent a letter to the Aerospace Industries Association requesting its recommendations concerning an outreach program, program management and strategic planning. Copies of these letters have been provided to the Committee staff.

d. The National Research Council (NRC) review of NASA's 90-day report has been sent to the National Space Council. Likewise, the Aerospace Industries Association review will be sent to the Council.

It is not anticipated that the reviews will affect the FY 1991 budget request. In fact, the NRC review has confirmed our view that a very large amount of work remains to be done to properly define SEI, and to develop the necessary technology, as well as to search for new ideas. The report reinforces the importance of receiving the funds which were requested.

EOS portion of the questions:

With respect to the EOS program, NASA has worked closely with the scientific community, taking into account previous NASA recommendations, and has utilized extensive university and scientific/technical reviews to arrive at the currently proposed program.

NASA expects the NAS will concur with the goals, objectives, and approaches that NASA has developed in conjunction with previous recommendations of the NAS. After an extensive review of the EOS program, the Office of Management and Budget (OMB) proposed a full new start initiative for the run-out EOS program. However, in order to guarantee that the science and engineering objectives were sound and met the goals of the U.S. Global Change Research Program, OMB also requested that the NAS conduct an extensive independent review of the U.S. Global Change Research Program to determine if the proposed NASA EOS program would meet the goals of this program and if our proposed approach is the most cost effective to achieve these results.

If the NAS recommends major changes, such proposals could have a significant impact on the direction, content, and timing of this initiative. However, significant agreement between our proposed initiatives and the NAS conclusions would allow us to move forward with early implementation of these initiatives. Such agreement would provide the scientific, regulatory, and policy communities with a definitive judgment of the program, which could contribute to major policy deliberations underway in the Congress and the international community.

The results of the NAS review will be presented to the Congress, to OMB, to NASA, to OSTP and the Committee on Earth Science, and to the National Space Council. The initial results will be available in early April 1990, with the final NAS report due by July 1, 1990. How these deliberations would affect the FY 1991 budget process depends in large part on what type of conclusions the NAS actually reaches. Relative agreement with our proposals would cause minimal or no impact on the pending FY 1991 budget requests. Recommendations for additions, reductions, or modifications in the proposed programs would presumably be taken under consideration by the agency and the Congress in their FY 1991 budget deliberations.

Question 2: The FY 1991 NASA Budget submission to OMB last fall was $16.6 billion. OMB cut that request to $13.7 billion which forced you to appeal directly to the President for support; and it appears you won since your FY 1991 budget request is $15.1 billion.

What was the case you made to the President to gain additional financial support? Do you think similar arguments will help convince the Congress? And to what extent is the President willing to directly involved in the battle for funds for NASA?

Answer 2: The budget proposal to OMB emphasized the importance of supporting the ongoing NASA program as well as the timeliness of initiating two significant Presidential initiatives -- the Earth Observing System as a key element of the U.S. Global Change Research Program, and the Human Exploration Initiative.

During the budget process, NASA accepted some reductions with impacts that could be accommodated but it was recognized that funding plans for the Space Station, Space Shuttle and Space

Science and Applications efforts could not be accommodated since the requirements were driven by the programs' technical requirements. In addition, reduced funding levels would substantially impact special initiatives in Aeronautics, Commercial Space and University programs which directly responded to Administration policies to enhance U.S. technological competitiveness, space commerce and education.

The President's budget reflects the Administration's firm commitment to NASA and clearly indicates NASA's high priority within the Administration.

There is a growing concern on Capitol Hill about the cost of operating the space transportation system. Based on unofficial estimates, the cost of each space shuttle mission could be as high as $370 million per flight. As a matter of fact, I understand GAO is looking into this matter.

Question 3a: What is your best estimate of the cost of each shuttle flight and what efforts are underway to contain the shuttle's cost? Does the concept of cost containment conflict with the desire of the Congress and NASA to maintain a safe reliable space transportation system?

b: What are the principal drivers of the cost increases in the Space Shuttle System --- unplanned work and overtime?

c: Was OMB's reluctance to fund the "new" Assured Shuttle Availability Account in the FY 1991 budget request a reaction to unforeseen increases in the Space Shuttle Program? How important is the ASA account to the safety and reliability of the Space Shuttle?

d: Does the proposed FY 1991 budget request slip the availability of the ASRM? Why did OMB cut this program request $60 million?

Answer 3a: Our current estimate is that the average cost per flight of Shuttle Operations will be $286 million (FY 1988 $) for the 10 flights planned in FY 1991 which should improve to $212 million to fly the planned 12 flights in FY 1994. Adding an allocation of R&PM and TDRS support would increase these cost by approximately $25-30 million. NASA's desire to operate and maintain the Space Transportation System in a safe and reliable manner is not in conflict with the concept of cost containment. It is true, however, that this cost of operating the Shuttle today has increased over the operating costs prior to the Challenger accident. The measures taken to reduce the risk to the vehicle and crew placed primary emphasis on the safe return to flight; undesirable overtime was reduced by adding more manpower to the vehicle processing activity at KSC; additional problem analysis and reporting systems have been put into place for continuing investigation of anomalies; procedures and operating instructions have been rewritten and added to provide for known contingencies; and the depth of personnel responsible for safety, reliability and quality assurance has been increased wherever flight hardware is produced and assembled for launch.

Since returning to flight in late 1988, we have flown 9 missions. The success of these missions to date is a result of our improved method of operations, but our experience is limited and there is still room for improvement. The main engine continues to be a source of concern due to its slow improvement towards its design life and the KSC work requirements are at a higher level than planned, the overtime rate is, however, much reduced since 1985-86. We have made progress in reducing the cost per flight although not at the rate we had hoped. The concept of cost containment does not conflict with the desire to maintain a safe, reliable space transportation system. However, containing and reducing the costs must be done carefully with full consideration of maintaining safety of operations.

b: The principal driver of cost increases in the Shuttle operations budget compared to last year is the unforeseen increases in the Solid Rocket Booster. The impacts to operations from the ammonium perchlorate plant explosion and recovery activity, as well as the Avtex rayon yarn recovery activity, has been significant. In addition, we have seen cost increases due to overhead rate increases at several major prime contractors. These were principally due to health benefit increases.

Unplanned work and processing requirements have resulted in overtime levels which are higher than we had planned and are resulting in higher costs. We are monitoring the overtime very carefully to insure there are no safety concerns and have instituted a comprehensive review of processing requirements with active KSC, development center and quality assurance participation.

3c: It is our understanding that the deletion of funding for the Assured Shuttle Availability was done without prejudice. We are in the process of redefining this program and plan to readdress the issue, at their request, during the FY 1992 budget cycle. The ASA addresses a fundamental issue of the long term supportability of the Shuttle program. It is not a near-term safety issue.

d: The FY 1991 budget request slips the availability of the ASRM. The first flight is currently projected for December 1995 rather than the 4th Quarter of FY 1994. The majority of this schedule change was caused by procurement delays while the issue of private vs. government financing of the facility and plant equipment was resolved. The $60 million reduction from the submission to OMB is consistent with the schedule adjustment.

Question 4: Last year, the Congress requested the Office of Space Science and Application to compile a cost containment plan as a condition for the new start approval for the CRAF/Cassini Mission. I understand the CRAF/Cassini plan is about 30 days behind schedule, but making substantial progress, and that the overall plan should surface in the July timeframe.

a. Is it possible for you to preview some of the findings and recommendations of these reports today?

b. What will these reports have to say about current cost estimating procedures, definition activities, and the role and responsibility of project managers (both government and contractor)?

c. Can the concept of "cost containment" be incorporated into one-of-a-kind research programs? What has been the experience to date within NASA and DOD with similar efforts?

Answer 4: The CRAF/Cassini cost containment plan will rely on a rigorous application of resource planning, managing, tracking and reporting procedures.

This document will be structured in such a way as to provide a consistent format for each and every semiannual report. In each category of OSSA Program Management activity, there will be a statement of the plan for CRAF/Cassini followed by a status report which will indicate performance with respect to the plan for the current reporting period.

The cost containment plan will underscore management's confidence in current cost estimating procedures, and will elaborate on the reasons for this confidence -- including the level of program maturity, the completion of thorough program and management reviews, and extensive study and evaluation.

Definition activities discussed in the cost containment plan will include a description of the Non-Advocate Review (NAR) process - this process helped determine technical readiness for the program and formed the basis of the cost estimates required before submission of CRAF/Cassini as an FY 1990 New Start candidate to the NASA Administrator. The plan will also describe NASA's plans to periodically conduct comprehensive cost reviews involving formal external review board membership (similar to the NAR) in conjunction with major project milestones such as the Preliminary and Critical design Reviews.

The roles and responsibilities of project managers for CRAF/Cassini have been given thorough consideration. The cost containment plan will emphasize the commitment by senior agency management to appoint seasoned managers to complex and challenging programs such as CRAF/Cassini. Experienced, senior NASA program management officials will be selected and assigned to CRAF/Cassini both for program management responsibility at NASA Headquarters and for project management responsibility at the Jet Propulsion Laboratory.

c: While it is true that the concept of cost containment may be more easily applied to large programs which produce many products, there are approaches to cost containment which have proven very effective in the one-of-a-kind environment of NASA. In every instance these approaches involve: (a) development of a complete understanding of all the cost risks in the program; (b) budgeting adequate resources to accommodate these risks; (c) retaining adequate resiliency in programs to allow for descoping which may be necessary when unexpected problems arise; and, (d) maintaining continuous vigilance through the application of appropriate human resources and management systems.

While we are not in a position to speak for the DOD experience, NASA has managed, over the course of its program history, to develop appropriate skills and systems to deal with "cost containment." Of course, a successful cost containment plan inherently and fundamentally depends on the maintenance of stable program financing and the preservation of initially budgeted program reserves. Fluctuating budget allocations or depleted reserve levels inevitably cause uncertainty in program planning and schedules, and often result in cost growth and program delays which no cost containment plan can possibly overcome.

Question 5: For the last few years, the Congress and NASA have tried to provide 20% of NASA's budget for Space Science and Applications. The Office of Space Science and Applications also has formulated a strategic plan based on this assumption.

a: Could you tell me what the percentage baseline for space science has to be in the decade of the nineties to support each of the respective science disciplines and to provide for a balanced space science program?

b: What is the effect of the Moon/Mars/EOS initiatives on the priorities outlined in the FY 1990 Strategic Plan for Space Science and Applications? Do space science activities related to these presidential initiatives now take precedence over previously stated priorities?

Answer 5a: In developing the OSSA Strategic Plan, we have assumed that the NASA budget will continue to grow to accommodate Agency plans, including Mission to Planet Earth and the Space Exploration Initiative, and assures OSSA will receive a proportion of the overall budget that is consistent with its historical allocation and its expended role in national initiatives.

b: As a result of the President's initiatives in Global Change Research and the human exploration of the Moon and Mars, the OSSA strategy is now composed of three interrelated, complementary parts. The first part is the core strategy that OSSA introduced in 1988. The second, an enhancement to the core strategy, reflects OSSA's lead role in the multinational Mission to Planet Earth, a key element of the U.S. Global Change Research Program. The third encompasses a strategy to fulfill OSSA's role in the Space Exploration Initiative.

The core strategy defines a program that OSSA should pursue even in the absence of overarching national and Agency initiatives. When such initiatives are undertaken, the appropriate resources must be added over and above the baseline. It is particularly important to note that the initiation of Mission to Planet Earth represents more than the beginning of a traditional OSSA science program. It also reflects NASA's role in a Presidential-level commitment to aggressively seek the understanding of global change needed to develop the predictive capability on which to base major policy decisions. Because the pace of Mission to Planet Earth is driven by this policy imperative, it will require a long-term commitment of resources to support that pace while preserving the vigor of the ongoing core space science and applications program.

OSSA's participation in the Space Exploration Initiative will be scaled to match the scope of the program for the Agency as a whole. The magnitude of each element of OSSA's contribution will be driven primarily by the pace at which the Nation proceeds and by the total institutional capability to pursue those activities in a way that adheres to the principles of excellence, balance, and appropriateness of approach.

Question 6: One of the largest proposed increases in the FY 1991 NASA budget request is for Space Research and Technology -- $210 million or an increase of 74% over the FY 1990 operating plan. The biggest winner is the Exploration Technology Program, formerly the Pathfinder Program that requests an increase of $153 million or over 500% in FY 1991.

a. Would the level of funding and the mix of activities in this account change dramatically if the Moon/Mars initiative were delayed? Did the proposed mix of activities place a high value on university participation and development of critical technologies with near-term market potential or was the program devised strictly to enable implementation of manned missions to the Moon and Mars?

b. Can a technology development program strictly benefit U.S. firms and industries if it is part of a civil/open program like Moon/Mars that will require significant international participation?

Answer 6a: The Exploration Technology Program is being planned as a national endeavor - with strong participation by NASA scientists and engineers, industry engineers and university researchers. It will require the best efforts of the entire U.S. technology community to accomplish the objectives of the Space Exploration Initiative. Investment in a strong research and technology program for the Space Exploration Initiative will inherently strengthen the technology foundation and infrastructure of U.S. industry.

Although the Exploration Technology Program is directed toward meeting the challenges of the Exploration Initiative, it will also benefit U.S. technological competitiveness. The technologies being proposed for development within the Exploration Technology Program substantially support numerous areas which are of critical importance to the broader national scene. For example, the Exploration Technology Program addresses vigorously many of the technology areas urged for development in the Aerospace Industries Association report on "Key Technologies for the 1990s."

A decision has not been made regarding either the architecture or the timing of the Exploration Initiative. However, the planned mix of activities and funding levels is appropriate at a time independent of when the missions should take place. The Exploration Technology Program will address the required technology developments in the areas of space transportation (including aerobraking and advanced space engines), in-space operations (including cryogenic fluid systems and in-space assembly and construction), surface operations (including space nuclear power and planetary rovers), human support (including regenerative life support and extravehicular activity systems), lunar and Mars science (including sample acquisition, analysis and preservation), information systems and automation (including high-rate communications and photonics), and nuclear propulsion. A strong research effort in these areas is needed to support national decisions in the early-to-mid 1990s regarding the content and pace of the Initiative.

b. The Exploration Technology Program will be implemented as a national partnership between NASA laboratories, industry and universities. As part of the implementation of the program, approaches will be devised that promote early and substantive transfer -- within the U.S. -- of exploration technology developments as they occur. The Space Exploration Initiative, and its key component, the Exploration Technology Program, will drive the development of numerous advanced technologies and industries within the U.S.

Potential international participation in the SEI is under review within the Administration. However, NASA has conducted many of its programs with significant international participation in the past. These activities are carefully structured so that each cooperating partner accepts full financial and technical responsibility for its portion of the cooperative project. By exchanging only technical information needed for effective interfaces, sensitive U.S. technology is protected.

Question 7: The FY 1991 NASA budget request includes a proposed increase of $60 million for NASA's contribution to the National Aero-Space Plane Program (from $59 million in FY 1990 to $119 million in FY 1991). At the same time, the DOD budget calls for a reduction to the NASP program (funding from $195 million in FY 1990 to $158 million in FY 1991).

a. How high a priority is NASP in the eyes of NASA? For example, is it a higher priority than the High Speed Commercial Transport for which NASA has requested only $40 million for environmental technology research in FY 1991?

b. What did NASA request for NASP in FY 1991 from Office of Management and Budget (OMB)?

c. Does NASA have any requirements for NASP? Does DOD?

d. To what extent will NASP benefit the U.S. aerospace industry? Is that why they have made significant investments of corporate funds?

e. Is the NASA budget request for NASP consistent with the National Space Council's proposed funding profile for the technology development program?

Answer 7a: NASP is a crucial National program with strong implications for continued U.S. aerospace preeminence. It is one of NASA's highest priority programs leading to technology for single-stage-to-orbit. NASP is a very different kind of program, with very different technology needs, from the High Speed Research Program (High-Speed Commercial Transport). The latter is also a very high priority in our aeronautics program as NASA is currently providing the leadership toward making such a system feasible in the early 21st century.

b. NASA requested and received $119 million from OMB. Both the NASA and DOD request are consistent with the revised program funding profile approved by the National Space Council and the President last year.

c. NASP is a technology development and demonstration program which will enable entirely new classes of NASP-derived vehicles (NDV) in the 21st Century. NASA's primary interest is for NDV's with fast, efficient access to space. There is similar interest in DOD, but there are also interceptor, long-range cruise (reconnaissance), and other potential mission applications as well.

d. The NASP program enables the U.S. aerospace industry to maintain preeminence in hypersonic technology and to continue its unique position to exploit advances in propulsion, materials and structures, computational sciences, and controls technologies for future aerospace vehicle applications. All participating contractors will be in position at the end of the flight test phase to bid on NDV's, which have the potential to provide substantial profits. The contractor investments to date have been in anticipation of the operational NDV's which will follow the NASP program.

e. NASA is fully supportive of the National Space Council's (NSpC) funding profile for Phase 2, and the FY 1991 request to OMB and the Congress is fully consistent with the NSpC recommendation.

Question 8: The proposed FY 1991 NASA Authorization Bill that has been submitted to the Committee by the President includes a provision to authorize the payment of $1.2 billion to the Federal Financing Bank to reduce all of NASA's outstanding debt to the Bank for the loans associated with the Tracking and Data Relay Satellite System.

a. Am I correct that of this amount, only $113 million will be scored against the Authorization and Appropriations bills? Why isn't the rest of this funding scored against the Committees?

b: Am I also correct that OMB and the Congressional Budget Office are in agreement as to how this matter will be scored?

c: Does NASA require both an appropriation and authorization for this provision to be in effect?

d: Based on the scoring associated with this matter, would I be correct if I indicated that the "real" FY 1991 NASA Budget Request is for $15.239 billion, not $15.125 billion?

Answer 8a: The $113 million outlay will not be scored against either the appropriation or authorization bills because it is derived from permanent borrowing authority that NASA has with the Federal Financing Bank (FFB) as part of the TDRSS contract. This amount represents the interest portion of NASA's regularly scheduled payment ($227 million plus refinancing costs) to the FFB.

The effect of recording the $113 million outlay is to convert all remaining interest on the TDRSS loan to principal. Therefore, the entire $1.2 billion repayment will be scored as a repayment of principal, which has no net budget authority or outlay effect on a government-wide basis.

8b: Yes.

8c: Yes.

8d: The "real" FY 1991 NASA Budget Request is the $15.125 billion. The difference between the agency budget of $15.125 billion and the President's FY 1991 budget total for NASA of $15.239 billion is the effect of borrowing the $113.8 million from the FFB for the final interest payment on the TDRS FFB loan. The $113.8 million is derived from the FFB permanent borrowing authority and not part of the NASA budget authority request.

Responses to written questions submitted by Sen. Bentsen.

Question 1: Given the uncertain future of the V-22, what is NASA's commitment over the long term to tiltrotor technology?

Answer 1: NASA remains committed to the tiltrotor. We believe that the payoffs of this new class of vehicle are too compelling to ignore. The tiltrotor will be developed in the future. The tiltrotor has had an important role in the NASA rotorcraft program and that continues today. Our emphasis in rotorcraft is shifting towards innovative configurations, such as the tiltrotor, which combine the vertical takeoff and hover attributes of the helicopter with the speed and efficiency of the airplane. The technologies we are working on today will enable tiltrotors of the future to be more economical to produce and operate. The U.S. currently has a substantial lead in technology for this class of air vehicle. However, foreign interest in tiltrotor and similar vehicles is high and growing.

Question 2: What part could NASA play to expedite the introduction of a civil tiltrotor into the transportation system?

Answer 2: Public acceptance and infrastructure development are the next major hurdles for the introduction of a civil tiltrotor. The FAA has taken the government lead in addressing these issues and NASA is supporting and cooperating in these efforts through simulations, studies, and technical consulting. In the longer term, NASA technology can also play a pivotal role in ensuring that the tiltrotor is both a friendly neighbor and economically viable to operate.

Question 3: In the Mission to Planet Earth, what efforts will be directed at determining the role of the oceans in global climate change? What role will NOAA play in this effort and how will the NOAA and NASA role be coordinated?

Answer 3: The candidate instruments selected for definition studies will measure all physical ocean parameters that can be measured from space. These candidates include: an Altimeter to measure sea surface elevation; a Moderate-Resolution Imaging Spectrometer-Tilt (MODIS-T) instrument to obtain state-of-the-art ocean color measurements and quantitative ocean productivity measurements; a Scatterometer to measure wind stress and the coupling between the atmosphere and the ocean; sea surface temperature measurements from MODIS-Nadir (MODIS-N); and the first quantitative sea ice measurements from the Geodynamics Laser Ranging System (GLRS). NASA is working with NOAA to archive several of these global ocean measurements. NASA and NOAA have worked together over the past several years to develop a closely integrated space observations and data information system. The principal coordination between the various Earth science agencies will be coordinated through the Committee on Earth Sciences, as demonstrated by the 1991 U.S. Global Change Research Program.

Question 4: What is the status of the SeaWiFS program to develop ocean color instruments?

Answer 4: The potential SeaWiFS program is a first attempt by NASA to work with industry to define a data product specification whereby industry would develop an instrument with specific signal-to-noise, wavelength location and bandwidths. Industry would have commercial marketing rights to the data for the first ten days, after which NASA would have full access to all data for research and development purposes. A Memorandum-Of-Understanding has been signed between Hughes Aircraft and NASA defining the terms of reference for such an agreement. Hughes is considering the implementation of the agreement, and we expect their decision in the early summer.

Responses to written questions submitted by Sen. Kerry.

There is a great deal of interest in the Nation, and in particular in the New England Science Community, in the new start request in the FY 1991 NASA Budget for the Earth Observing System, the first phase of the proposed Mission to Planet Earth.

Question 1: What is the level of funding requested for this initiative in FY 1991 and what is unique about the way this program is being packaged? For example, what is proposed breakdown of funding for science activities, data activities and hardware activities? And how does that compare with other space science programs?

Answer: The total FY 1991 funding request for the Earth Observing System (EOS) is $235 million. Of this total, $132 million is for the development of the first polar platform (transferred from the Space Station Freedom). The approximate breakdown of the remaining funds is as follows: $20 million for science efforts for the Principal Investigators and Interdisciplinary Scientists; $32 million for the EOS Data and Information Systems (EOSDIS); $42 million for science instruments; and $9 million for the other platforms and management associate with the overall EOS program.

The most unique aspect of the budget planning for the total EOS program is that, over the life of the project, 60 percent of the EOS budget will be spent on the EOSDIS, support to scientists, education programs, and related activities; only 40 percent will go toward the space hardware elements of the program. On a typical space science mission, only 30 percent of the funding is allocated to science and data, while 70 percent is normally spent on the space hardware. The ratios for EOS indicate the strong NASA commitment to quality science and data operations for this critical program.

Question 2: Am I correct that part of this new initiative is an EOS Fellowship Program? Could you provide me with information about this program so I can let the New England universities know?

Answer:_ We have identified specific funding in the EOS budget to establish Graduate Student Fellowships in Global Change Research. Starting with 25 fellowships to be awarded in 1990, the program will fund up to 150 graduate students per year for the duration of the EOS mission.

Awards will be made for an initial 1-year term and may be renewed annually up to 3 years, based on satisfactory progress as reflected in academic performance and evaluations by the faculty advisor. Applications will be considered for research on global biogeochemical cycles, radiation and physical climate interactions, the hydrological cycle, and solid Earth processes. Atmospheric and ocean physics, chemistry and biology, ecosystem dynamics, soil science, geology, geophysics, and cryospheric processes are all acceptable areas of research, providing that the specific research topic is relevant to NASA's global change research efforts (the Earth Observing System and Mission to Planet Earth). The announcement and proposal application is attached.

Question 3: How high a priority is the EOSDIS program and what is the anticipated funding for this initiative over the next three years? Can EOS be successful if EOSDIS is not successfully implemented?

Answer: The EOSDIS is the highest priority element of the EOS program. NASA does not believe that the Earth Observing System can be successful if the EOSDIS is not successfully implemented. The EOSDIS is critical to the success of the U.S. Global Change Research Program. Over the life of the EOS program, EOSDIS, science, and operations will constitute about 60 percent of the total resources of the EOS program. While exact funding levels for the EOSDIS over the next three years have not yet been determined, NASA has a strong commitment to bring the system on-line as quickly as possible.

Another project that has attracted a lot of attention in New England is the next great observatory - the Advanced X-Ray Astrophysics Facility (AXAF).

Question 4: Would you please give me a status report of this project and am I correct that in the last report to Congress in January of this year, the program was making great strides in the key technology areas?

The Advanced X-ray Astrophysics Observatory (AXAF) mirror development program is progressing satisfactorily towards a Spring 1991 completion date. The last report submitted to Congress, in January 1990, describes the details of the program and the progress to date. A copy of the report is attached. Since January, additional progress has been made in a number of key technology areas. The Automated Cylindrical Grinder/Polisher passed an operational inspection and has begun grinding the inner surface of the largest parabolic mirror element, identified as P1. The Circularity and Inner Diameter Station also passed an operational inspection and has been used on P1. Finally, we have started polishing the outer diameter of the largest hyperbolic mirror element, identified as H1.

Question 5: Is the program on schedule and does it now appear certain that the technology challenges will be met and this program become a reality?

Answer: The AXAF program is on schedule for meeting its Spring 1991 target date for completing mirror development activities. Although much work still remains to be done to achieve completion by Spring 1991, we have successfully met the technology challenges addressed to date and are confident that we have the appropriate people supporting the AXAF program to address any future challenges and to make this program a reality. Much has been accomplished in this program since its initiation in 1989. This is the result of the dedicated efforts of many people, including the TRW, Hughes, and Eastman Kodak contractor teams, the project personnel at the Marshall Space Flight Center, and the optical and scientific support staff at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts.

Finally, I would be remiss if I did not ask for an update on the progress in establishing international space docking and rescue standards.

Question 6: To what extent has NASA interfaced with the Association of Space Explorers who have done significant work in this area?

Answer: NASA is familiar with the activities of the Association of Space Explorers (ASE). While the Association does not operate on a regular basis, has no permanent staff and no official responsibilities, NASA stays abreast of the activities of the Association in the area of international space docking and rescue through review of ASE conference proceedings and papers presented by ASE representatives at technical conferences and interaction with key individuals within ASE. The primary focus of NASA's efforts on international space docking and rescue standards is through the Johnson Space Center (JSC), Houston, and direct interaction with our international partners on several programs, most notably the International Space Station. We are planning an International Conference on Spacecraft Rendezvous and Docking at JSC. A target date of May 21, 1990, is being coordinated with the USSR, ESA, Japan, and Canada.

Question 7: In the era of Glasnost, wouldn't a simulated space rescue mission promote good will between peoples of the Soviet Union and the United States? Is NASA assessing such a mission or even the exchange of astronauts and cosmonauts as a first step in familiarizing each other about the standards and techniques used by each respective nation?

Answer: NASA submitted a detailed report to Congress in April 1988 on its study of international spacecraft docking. Based on this study, NASA believes that the establishment of a set of international rendezvous and docking interface standards and conventions could be a first step toward international docking capability for some future spacecraft and missions. NASA is presently engaged in the necessary planning and coordination to convene an international technical meeting in the United States with participation by representatives from the space agencies of spacefaring nations, including the Soviet Union. This meeting will address all elements of the rendezvous and docking function. The objective of this meeting is to describe the existing capability of each participant nation's spacecraft and define the technical issues that would require resolution in order to achieve future interoperability of spacecraft. This fundamental first step is required before we could consider any more ambitious steps.

A simulated space rescue mission was proposed to the USSR by the U.S. in 1984. This offer was tacitly rejected by the Soviets, perhaps because of the inherently non-reciprocal nature of the mission. In brief, orbital mechanics would allow the U.S. Space Shuttle to rendezvous with Mir. However, no known or planned Soviet manned system would be capable of reaching the orbit of the U.S. Space Station from any Soviet launch site.

Senator **Gore**. Thank you very much, Admiral. I thought that was an excellent statement. In your prepared statement you cover some other points as well in an exemplary fashion.

Before going to questions, let me ask, J.R. Thompson, would you like to share any words to supplement Admiral Truly's statement?

Mr. **Thompson**. No, Senator, I think I will probably pass at this time. I would just say that in my 25 years with NASA I believe this is the most balanced budget, balanced NASA, that we have seen, and I think these are exciting times and certainly we are going to need the support of this Congress.

Senator **Gore**. Mr. Campbell?

Mr. **Campbell**. No, sir.

Senator **Gore**. All right, very good.

Let me begin with a statement about the context within which we receive this request. I am one who has argued consistently in favor of a more ample budget for NASA. It has been apparent to this committee for quite some time that NASA and the country were not being well served by the pretense that flat budgets could suffice for programs which were undergoing a natural evolution toward a higher spending profile as the several large components of NASA's ongoing agenda reached maturity.

I commend you for your success in persuading the Administration to begin recognizing that fact. Now, along with a recognition of the maturation process in these ongoing programs, you have also brought some new starts which have a maturation process of their own, and which will lead to larger budgets in the future if they follow the course now intended for them.

These developments occur at a time when the overall budget is under great stress, and as an enthusiastic advocate of adequate funding for NASA's programs I want to be able to tell my colleagues on the Senate floor that this is a realistic request.

Let me give you an appreciation for one of the difficulties we are going to encounter there. I am hopeful we shall prevail, but I want to put it in context before coming back to the NASA budget specifically.

The Associate Director of OMB, Mr. Robert Grady, who is a very capable man, but also has to deal with the macroeconomic context within which these issues arise, was asked recently where the money is going to come from for the increases in the NASA budget.

He was interviewed in a publication called "Space News," and he gave one of the most honest and thorough answers I have seen from an Administration spokesman, and I want to quote his answer to the question, "Where is the money for these increases in NASA, one of the largest for any agency in the government, going to come from?"

And I quote here at some length. The OMB official, Mr. Grady, says:

> Four things allow this investment in the future. One is new revenues generated by the continued growth of the American economy, and that is worth some $83 billion in 1990 and 1991.
>
> Two, a handful of user fees will generate new revenues and new tax laws. Some are small ones. For example, the Corps of Engineers dredges channels around the country and we slightly increased the fee that ships and barges pay to use the channels. The big one is the capital gains rate reduction. In total these generate about $13 billion.

The third category is interest rates. Very fortunately, they are going down and some of the national debt is retired from earlier years when interest rates were very high.

Fourth are reforms in the mandatory section of the budget and in low return programs. Some cuts were necessary. There is a reduction in Medicare. There are cuts in the agricultural programs. There are small cuts in areas like fossil energy research and development. The handful of mandatory program cuts total about $14 billion, with discretionary program savings of $15 billion.

That totals $125 billion. We took $60 billion off the deficit, so that leaves $65 billion to fund new initiatives above 1990.

The problem is, as I read this answer, that the identified sources of funding for NASA, along with the defense spending issue, are the primary sources of contention this year in the Congressional budget process and the dialogue between the Congress and the President.

If we could agree on the economic forecasts, user fees, revenue enhancements, capital gains, I guess we could somehow magically find $16.3 billion for NASA with no problem. But after a decade of debate, we still do not have a consensus on budget spending priorities and revenues, and therefore the augmentations throughout the President's budget request for science and technology become targets for reductions.

Now, the reason I go through that exercise is, at the start, is that the logic you are using is compelling to me. The justification for your presentation this morning is ample in my opinion. But in responding to it and reacting to it, this committee has to keep in mind the context within which our request made to the full Senate will be received.

As long as the President of the United States is willing to swear on a stack of Bibles that we need neither new revenue nor major structural changes on the spending side, then the argument in favor of justified increases, such as the ones you are requesting here, is going to be very difficult to make.

Now, that is not in your list of assignments, but it is in ours, and so I wanted to say on the front end that there is an air of unreality still in the Administration's overall approach to the budget.

I am very pleased that my senior colleague from Tennessee, Senator Sasser, is doing such an outstanding job in pointing out these matters and searching for bipartisan solutions.

Now, let me move back to the NASA budget in and of itself and look at the area of space policy within which we are going to be reviewing it this morning. In 1981, nine years ago, despite the fact that spending for NASA was only $5 billion compared to this year's request of $15.1 billion, the United States dominated the world's launch services, communications satellite, and remote sensing markets. And yet today our leadership in these fields has been seriously eroded and the threat of foreign competition becomes more severe on an annual basis.

If this trend is not corrected, the United States could become dependent upon foreign services in these three areas. These are matters of great concern to the committee. What is the relationship between your budget request submitted here today and the competitive posture of the United States of America, particularly our aerospace and space industry, in world markets in the areas that I have highlighted here?

Will your budget request do anything to enhance the competitive posture of the United States in satellite launching, communications fields, remote sensing markets? Will this budget request ensure the development of critical technologies?

Will it add stability to the base of employment in the nation's aerospace industry? Will it halt the erosion of the U.S. space industry market share to foreign competitors? Those are several parts to the same overall question, and I would very much like your views on that.

Admiral **Truly**. Thank you, Mr. Chairman, and I would be pleased to give them, because I think there is an absolutely direct connection between NASA funding, NASA technology, NASA programs in aeronautics and space, and American competitiveness.

As a matter of fact, the aerospace industry in this country leads the way on the favorable side of the ledger in balance of trade. Last year this industry contributed almost, I believe it is, almost $19 billion in black ink in the balance of trade that directly is attributable to American competitiveness in aircraft production, that stems from aeronautics research at NASA, and also throughout the industry itself.

I believe that this is not an accident. I believe it is because in past years we have funded NASA research in certain areas that finds its way to those American companies.

However, I must tell you that the trend, even though we are large, for example in aeronautics, even though you go to Heathrow, you go to Paris Airport, you go anywhere around the world, and down the line you see U.S.-built aircraft—747's, McDonnell-Douglas aircraft, L-1011's, and so forth—the trend is that other nations are beginning to, not take over that market, but inch into it.

We see major competition, for example, in aircraft design with the A-320 Airbus built in Europe, where they have done what we need to do, and that is they have made aggressive application of technologies that have been developed as a part of research programs in composite materials for primary structures, for fly by wire flight control systems as an example.

I do not know of another Federal agency where in my own view there is such a direct connection between technology and competitiveness. Our entire purpose at NASA is first to provide the nation with a civil space program that the country can be proud of, to do research in aeronautics. And in the 1958 Space Act it charges us with sending this technology to American companies.

Naturally, we can always do it better. We certainly are going to continue to try. But to walk away from that investment I believe is walking away from the future of the country, and that is the reason that I find it so easy to discuss it.

J.R., would you care to add anything?

Mr. **Thompson**. No. I think you could reach into the space technology area and just look at some of the things like materials, where it is driving, I think, the competitive edge in this country and doing the same thing in space that we have done historically in aeronautics.

So I think there is a thread throughout the NASA programs to keep America first. I think the issue is are we going to continue to make that investment, and a lot of that is what this hearing is all about.

Senator GORE. Let me refine the question and ask it in a slightly different way. Your answer is to say essentially that there is a connection between NASA and the U.S. aerospace, communications, remote sensing industries, and when we help NASA we do help our nation's ability to compete in these areas.

And I do not dispute that. That is obvious on its face. But something else is obvious on the face of the problem, which is disturbing. As we have continued to make these sizable investments, America's competitive position has been declining fairly rapidly in the area of launch services, in the area of aerospace, in the area of the space industries, and the communications satellites.

Is there anything in this budget request which represents a difference, a new departure, an effort to stop this decline in America's competitive posture in these areas where we have always assumed that NASA was helping us to remain competitive? Or is it more of the same? You know, I do not mean that to sound pejorative, but do you agree that something different needs to be done and, if so, is it reflected in this budget request?

Admiral TRULY. Well, first of all, let me say that I think I tend to agree with you. In the months since I have been NASA Administrator I have been doing a lot of reading on a very broad national economic scale, particularly in this industry, and over and over there is a theme, that somehow U.S. industry, U.S. companies, U.S. economy is finding it harder and harder or has found it harder and harder to take technology and move it quickly, rapidly, and efficiently to the marketplace so that we can continue to compete, as we watch other countries be more successful than we have in certain areas, in taking their technology and in some cases our technology and moving it into the marketplace.

However, I must say that I think in this budget itself that there is not something that I am aware of that fundamentally funds something in our appropriated line that would change that. I think that it is a problem that is going to have to be addressed at a very macro level, between the leaders of our country in manufacturing and in productivity as we in government deal with the heads of these companies, and in that sense there are some things that are going on, I think, that are increasing the communication between we in the government and in the private industry.

Senator GORE. Well, let me just express some specific concerns. We are not in my view moving toward clear goals in advanced launch technologies. We are dawdling on the National Aero-Space Plane. We are uncertain with respect to high-speed civil aviation.

Many matters which seem critical to the future competitiveness of America's aerospace and space industries are being maintained and routinely serviced by NASA now. In some cases you are having to pause to look at problems that need analysis. We understand and respect that.

I also agree that the generic problems of how we set goals and pursue them in a singleminded fashion with coordination between and among various parts of the government, those issues have to be addressed at the White House level, and they have not been in my opinion. I will not ask you to comment on that.

But I did want to express those concerns, and these are subjects which we will continue to discuss during our hearings this year and during our dialogue with you.

If you want to supplement your response on that for the record, or any of these others, you are welcome to do that. But I would like to move on if you are prepared to.

In 1961 President Kennedy, of course, challenged this nation to send a man to the Moon and return him safely to Earth, and the President gave NASA ten years to meet his challenge. NASA did it in eight, despite the fact that we were starting from square one and had to make significant technological breakthroughs.

Yet, six years and $3 billion after the initiation of the Space Station program, we are still in the design phase of a program that was marketed as being off the shelf. Has NASA, has the nation, lost its ability to quickly implement challenging new initiatives?

Can you quantify, can you list and prioritize, the obstacles which have made for such a difference between our response to the challenge of the Space Station and our response to the challenge to put a person on the Moon and return him safely?

To what extent did the ethics restrictions, procurement regulations, budget deficits, and shortages of critical human resources exacerbate NASA's problems concerning the development of a permanently manned Space Station? Is the resolution of these kinds of structural issues critical to NASA's ability to initiate and successfully implement future initiatives?

Admiral **Truly**. Mr. Chairman, let me comment first to the first part of your question that referred back to the 1960's and the Apollo era. We were working in the space program in the 1960's as well as we are here today in the 1990's, and it was a far, far different environment.

Senator **Gore**. Were all three of you part of NASA at that time?

Mr. **Thompson**. I was.

Admiral **Truly**. Yes.

Mr. **Campbell**. Yes, sir.

Senator **Gore**. You were in the astronaut corps at that time, Admiral Truly?

Admiral **Truly**. Yes, I was.

Mr. **Thompson**. I was involved in the development of the engines on the Apollo program, and Tommy was working the budgets.

Senator **Gore**. The budgets on those engines.

Admiral **Truly**. And a significant difference is that people working on budgets in the 1960's were far more successful than they have been on the Space Station.

Senator **Gore**. It was more fun then, was it not? Your job was more fun then, was it not, Mr. Campbell?

Mr. **Campbell**. It certainly was.

Senator **Gore**. Go ahead.

Admiral **Truly**. The investment in NASA rose from almost nothing in 1960 and 1961 to 3.8 percent of the Federal budget in about three or four years in those early budget authority years. We literally in those days were able to swamp technical problems with money and engineers and scientists, because it was the national will to do that program.

Furthermore, the Apollo program and Gemini and Mercury leading up to it, but the Apollo program was the space program. It was the single objective of the program in the 1960's.

Today it is far different. First of all, in the question you asked about it, but you probably could have asked about it in some other programs that we have, what we have seen in the Space Station program is a funding see-saw, an instability in funding as each year has gone by.

Second, today's space program is far more complex than it was in the 1960's. Today it has matured, and that is good. It has a very complex and wide-ranging unmanned scientific program. It has a large and complex transportation program to run for many different purposes, not just a few flights to go to the Moon, but flights to deliver satellites for other nations, for other agencies of the government, and for NASA.

So I think I would challenge the point that we have lost the ability to produce the same kind of performance that we had then. What we have lost the ability to do is to argue successfully for the kind of financing and budgets on a stable basis to allow us to deliver in a better fashion. And when we do not deliver as well as we should, it is something that concerns us very greatly.

But the total environment has changed.

The second part of your question I believe had to do with something that has concerned me extremely much in the last years, and that has to do with public service itself—ethics regulations; you did not mention it, I do not think, but I would, pay for people that work for NASA, engineers, budget people, procurement people, facilities people, secretaries, the kind of people that it takes to run the government.

We have lost some good people in the last two or three years, and that fact has gotten itself into the media. But I would say that we did not lose a lot of people. The people that we lost were people that I hated to see go. They were as experienced in the space business as anybody in this hearing room.

I have seen a definite change just in the last few months about the stability that is provided to our people with the knowledge that there is going to be a Federal pay raise to be in effect in 1991.

Do we have to solve those problems in order to keep the core people to do our programs? Absolutely, we do. Are things better off now than they were just six months or nine months ago? I think they are. I think there is a recognition of this, of the importance of public service. The pay situation has helped.

So I see the future brighter. But I will tell you, when I look at someone who is coming to work for NASA and look at the opportunities that they have financially working in the same business in the private industry, I sometimes wonder why they are willing to make such sacrifices.

Senator GORE. Well, again, if you wish to supplement your response on that we would be interested in further thoughts on that.

Mr. THOMPSON. Senator, let me just add one thing, and that is it is true that we are still five years away from launching the Space Station, but it is not on the drawing board today. We are doing an awful lot of testing throughout NASA: at Langley on structures, at Lewis on power systems, down at Marshall on environmental control systems, and at Johnson, data systems and information systems.

So we have now turned the corner. I believe we have got a lot going on and it is going to be very important this year now to maintain that momentum. We are far beyond the viewgraph and the drawing stage. We are now into let us go do it.

Senator **Gore**. What must be done in fiscal year 1990 and fiscal year 1991 to guarantee deployment of a permanently manned Space Station within this decade?

Admiral **Truly**. It is the budget, Senator. The request that we have before the Congress for Space Station in 1991 is absolutely required to keep us on schedule and to keep the content in the station program.

Even with that budget, it is going to be a tough job. This is the year that the Space Station, throughout all its subsystems and major systems, will go through its preliminary design reviews. But we have got a hard-nosed management team in place. We have got a configuration that we have been through several times and has stabilized.

We have dealt with our international partners, and they are our partners and are putting in a goodly share of the money.

But we need to get off this instability in the program and allow us to go manage it, build it, and fly it.

Senator **Gore**. Well, your hard-nosed management team on the Space Station has gone nose to nose with an even harder-nosed OMB team scrutinizing the Space Station. At least that is how it appears from our vantage point here, because even though you have stated clearly what is required in order to regain the momentum and make this program successful, last fall, due to OMB's pressures, NASA was forced to seriously reassess the content and schedule of the Space Station program.

Less than six months later, OMB eliminated $130 million of contingency funding from the Space Station request, and at the very same time OMB was more than willing to provide $188 million in brand new money for a major new initiative, the Mars program.

Now, would not NASA be a lot better off if the funds requested for the Mars program were assigned to the Space Station program to increase the available power for the man-tended and permanently manned Space Station? And does not the reduction in the contingency fund in fiscal year 1991 increase the risk of further slippage in the schedule and further cost increases in the Space Station program in the future?

Admiral **Truly**. Mr. Chairman, I can assure you that neither my hard-nosed Space Station managers nor myself was delighted to see that we had to see a reduction. But it is a small reduction from our original request to OMB, and it does most certainly tighten up the program, which we did not want to see.

But it was something that we did believe was acceptable for the place that the program was in in order to get through fiscal year 1991, and so in a sense we were a party to that as we went through an entire request, not just for Space Station but for a balanced NASA budget.

So yes, I asked for the money. No, I was not pleased to see that particular money not be a part of our budget. But yes, we together with Dr. Lenoir and Dick Kohrs, who run the Space Station program, decided that it was a management challenge we were willing to accept.

As to the part of the question about, would we not be better off if we took the money from the exploration initiative or from some other part of NASA and applied it to Space Station, I would say on balance no. I would say a portion of the money in the Moon/Mars initiative will go to examine how the Space Station should be evolved and improved in the future in order to do that mission.

Senator GORE. How much of the $188 million will be applied to that?

Admiral TRULY. About $20 million.

Senator GORE. About $20 million?

Admiral TRULY. About $20 million, yes.

Senator GORE. Will go to study how the Space Station will be changed?

Admiral TRULY. Yes. What we have done is, in the $188 million for the initial technologies for the lunar and Mars initiatives we have made a preliminary judgment of how we would apply that money to different technologies, and a small amount, about $20 million, will be taking a look at Space Station evolution.

So on balance, the reduction did tighten up the management of the program for fiscal year 1991, but we were willing to accept that.

Senator GORE. I have some questions about the Human Exploration Initiative, the proposal to go both back to the Moon and Mars. But I will save those until a little bit farther along in our hearing here.

Staying with the Space Station for a moment, I have expressed the concern in the past about whether or not our foreign partners are going to sit still for a further whittling away of the U.S. part of the international Space Station program, of which we are the principal part. We have scaled it back. We have changed the capabilities of the station.

We have pressed right up to the limit of what the foreign partners feel is fair. Have we gotten to the point where now any further cuts in the Space Station program would seriously affect our international agreements?

Admiral TRULY. I think we are to the point this year where our national credibility is on the line with funding the Space Station. We did go through negotiations with our partners last year when we reacted to Congressional cuts in the fiscal year 1991 appropriation, and you saw for yourself the difficulty that we had with our partners, as we had no choice but to react to those cuts, take a look at the content and the schedule of the program.

I think that we have gotten over those times very well. We have a program that is well in hand. But I think a major reduction to Space Station funding in fiscal year 1991 would cause them to look very seriously at their commitments to the project.

Senator GORE. All right. Now let me move to another subject. Last year, despite the fact that, number one, the NASA budget request was not enough to cover the ongoing programs, and second, that several privatization initiatives were included in the budget request which significantly reduced the identified budget requirements, the NASA budget request was further reduced by Congress because of the severe budget pressures to which I alluded in my first statement after your opening statement.

Despite these reductions, several new starts were approved by Congress, including the $1.6 billion CRAF/Cassini program. What would be your reaction, Admiral Truly, to a policy which said, unless ongoing program requirements are met, no new starts can be initiated?

Admiral TRULY. Let me make two comments to that. First of all, I think that is basically the approach that we take today, and that is why in presenting to you the fiscal year 1991 request the large predominance of the request, 98 percent of it, is for programs that have already been approved, and it is the money that is required to move into the next year.

So I think in general we look very hard internally, and naturally the White House, OMB, looks very hard at us when we go through their wicket to start up new initiatives.

The second comment that I would make to the question would be that I think it would be a great mistake, and I think you would see our space program begin to die if you did not have new exciting projects that were in the future, that our people, our contractors, the American people, could watch us look into the future to do.

One of the great things, I think, about NASA is that, of all the Federal agencies, I think we are probably the only one that literally works on programs that are 10, 15, 20, 30 years into the future, and to lose the ability to be able to prudently start the most, the highest priority of our new starts, I think would be devastating.

Senator GORE. Well, I agree with that answer. I think it is a persuasive answer. But there is another side to the question because, if we get into a position where we are constantly launching new starts and constantly cannibalizing the ongoing programs, then we risk getting into a state where NASA cannot do anything well and there is just a big logjam. The agency would be paralyzed and every ongoing program cut down to the bare minimum. Nothing then really moves forward well.

Some people see some signs of that from time to time in some of the programs that have been delayed for so long. Do you?

Admiral TRULY. I do not disagree with that at all. I think that NASA has to be very attuned to demanding the sorts of resources that allow us to meet our commitments, and we have been bad about that in the past in some cases. We have people that love to take on new jobs and they have not been as insistent, I think, asking for the moneys, for example, to keep our facilities up or asking for the money to make sure that we have the number of people.

But I would say that the situation as I have watched it evolve in my four years at NASA headquarters, particularly after the Challenger accident, has given me great heart that we are doing much better. And I think a result which I think is very promising is the fact that, as I said, this 1991 request is so much better balanced than our past requests have been.

Senator GORE. Well, just to make certain that we are balanced here in the committee in asking these questions and making these points, I want to include in the record [1] a recent National Academy of Engineering report rating, after much study and review, the top ten engineering achievements worldwide of the last 25 years.

The Apollo program was number one on the list, and several other NASA projects were listed, and I want to put that in the record of this hearing. When we take our budget request to the floor of the Senate, I want to put that into the Congressional Record and highlight it for my colleagues as well.

Now let me shift gears again and explore with you a subject which has been of great interest to me, and that is the issue of data management in NASA and network in NASA. We have had a chance, Admiral Truly and Mr. Thompson, to talk about this privately. I see others in NASA here in the audience with whom I have had a chance to discuss this.

I was very distraught to read the GAO report about NASA's data management problems. The "Wall Street Journal" headlined its story: "What happens to most NASA data taken from space? For the most part, nothing."

This GAO report came out after we had already had a number of discussions with NASA on exactly the same subject. Now the report states that NASA has failed to appropriately store and use its magnetic tape data base and that the current situation is, and I use their word, "deplorable."

Admiral, when somebody reads these kinds of articles and reports, how can they feel confident that the data to be generated by the Earth Observing System will be effectively utilized? It is my understanding that the amount of data contained in the entire Library of Congress, the largest library in the world by far, and that much data will be collected by NASA in the EOS program in 24 hours. Every single day that amount of data will be added to the new store of data which NASA has.

This is the single biggest challenge in Mission to Planet Earth by far and yet the record, as I have said, is not a good one. I have had a chance to review the data bases compiled by NASA and compiled by other government agencies as well. We will soon have a hearing on that specific subject.

We have had trouble getting NASA and the other agencies to even find the list of data bases. The information about the information has not been stored well. It was as if the Library of Congress card catalogue was missing. It is kind of a mess as far as I can tell.

In our agricultural policy, we store surplus grain in silos until a lot of it rots, while at the same time people die of starvation and persistent famine in many parts of the world. We have an information policy in NASA and elsewhere in the Federal government which is similar. We collect and store mountains of surplus data which sits there in silos, so to speak, and rots, while we hunger for information about what is happening to the Earth's climate system and searching for ways to better understand how this planet operates.

While we have this great disparity between the mountains of data nobody has looked at and the great need for that information, here NASA comes and proposes a giant new program to collect much more data in a single day than already exists.

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[1] The report was not reproducible.

I am comforted only by the fact that I know you have recently begun to pay attention to this, and I have such great respect for your abilities as a leader to believe there is some hope that you will be able to get this problem in hand. But it has not been handled well up until now.

I frequently use the example of Landsat. 95 percent of the images of the Earth collected by Landsat have never fired a single neuron in a single human brain. The pictures have not been looked at by anyone.

Here we are embarking on a mission to answer questions such as, for example, where are the clouds, what has happened to the pattern of land use on the Earth's surface, and we are proposing to collect brand new information for 17 years and study it and try to answer those questions, while we have in storage a complete picture of the Earth's surface taken every two weeks for the last 20 years and we have not even looked at it, and that is just in one system.

I think it is crazy not to place the number one priority on going back and sifting through that information in a very intelligent and determined and systematic way, to create the algorithms and the other tools we are told are needed to sift through the data quickly and electronically, and pull out the specific data sets needed to answer the priority questions which are driving the Mission to Planet Earth program.

Now, some hear these objections, which I have expressed in private before now, and hear opposition to the EOS program. That is a misinterpretation of what I am saying. I believe we need to continue to collect information and we need the additional quantities and kinds of information that EOS will give us to perfect our understanding of what is going on with the Earth's planet system, with the Earth's environment, and to monitor and assess the viability of response strategies as the world haltingly moves toward a global strategy for dealing with this unprecedented problem.

But we need the answers quickly when we can get them quickly. We need to catalyze the consensus now in formation around the world for addressing the problem and making the sometimes difficult changes in policy needed to solve the problem.

The answers, a lot of the answers at least, are in storage inside NASA, in magnetic disks and in other information storage media which have been in part allowed to decay, have not been well taken care of, and, most importantly, have not been analyzed.

What actions can you tell us about today that you are going to take to correct this situation? What can we do to help you in the fiscal year 1991 bill to make sure that existing data sets are thoroughly inventoried, that valuable data is processed into accessible formats, that are well maintained and managed?

And in your response, please try to give us some understanding of how a situation like the one described in the Wall Street Journal article and the GAO report could be allowed to happen.

Admiral TRULY. Thank you, Mr. Chairman. You have asked several things and I would like to start with that GAO report, if I might. You said that you were distraught when you read the article in the "Wall Street Journal" and the report. My reaction when I read the report I would describe as more violent than that.

But when I looked into it and when I have looked into it in a draft of that report before Christmas and even as it has just been presented, and we have I think—after it is formally presented to us, then we will have 60 days to reply—I must tell you that I believe that it is absolutely off the mark.

I think it is overly harsh to a program of 25 years of providing science data to users, that certainly has its problems. No program that deals with literally tens of thousands of magnetic tapes cannot run perfectly.

But there is no evidence that we can find that there is any significant loss of data, loss of science data, and I believe the report has made sweeping implications about the basic quality when in fact it should have recognized the problems that we have recognized in the program and what we are doing about them.

For example, one part of the report refers to a large number, about 130,000, data tapes that were sent to a Federal data storage center by the Jet Propulsion Laboratory, not a NASA facility but a Federal facility, and the implication in the report was that if we looked at all those tapes we would have lost about half that data.

In fact, you asked what we have done. In that particular case we have removed all those tapes, we have returned them to JPL, and we have now looked through about 35,000 of them, and we have not lost the data.

So I believe that this discussion on the particular report is going to take a little more time for us to deal with. But I just believe that it is unduly harsh of our work.

The second——

Senator GORE. Before you go to the second part of your response, let me make clear that I believe the more serious problem is one not really addressed in the GAO report, and that is a failure to analyze and use and make accessible the information that has been collected. Some of that has been done, but most of it has not been done.

With respect to the GAO report, however, I have seen enough reports and studies and problems to know that sometimes some of them are unduly harsh and unfair and you cannot really get a balanced picture until you hear the other side of the story.

As I understand it, at this stage in the process NASA has not yet given its formal written response to the GAO report; is that correct?

Admiral TRULY. That is correct.

Senator GORE. When is that due?

Admiral TRULY. I do not think we have formally been—I have been given an advance copy. I am not sure we have even formally been sent the report from the GAO. We may have, but if we have it has been literally in the last hours or day or so.

We will receive it, though, and we will respond to the Congress and the GAO responsibly with it. I just want to make it clear to you that we are not going to ignore it. I do think it is harsh on us.

As a matter of fact, I asked J.R. Thompson just yesterday. He might want to comment. He spent the day up at Goddard and visited the data center up there.

Mr. THOMPSON. I would just, I think, echo what Dick said. I found the report to be totally out of balance with the facts. I think in terms of archiving the data we have got, it is I think in as good a shape as any library you can go in across the country.

So I think, frankly, we are in good shape there. There are some things, as with any system, that I think we can do to tighten it up a little bit, and believe me, we will do that.

I do agree that the more important issues are the other two that you mentioned, and I did spend a few minutes talking with the people at Goddard, because they are very much involved in that. And yes, you have certainly got the attention of both Dick and myself and I know Len Fisk relative to the issue of are we extracting enough from the data we have already got. And I will let Len perhaps comment on that.

But I did also spend some time at Goddard talking about how are we getting this information out to the users, how do they know what is there? And I will certainly leave this with you, but we have got a master directory. We send out inventory menus of the tapes that we do store in the archive system.

It is just now starting, but I believe we are beginning to turn up the wick on this subject. It is very important, but it does have our attention.

Just briefly coming back to the GAO report itself, I was quite pleased with what I saw, having read in detail the report. I know that Jack Townsend, our center director, is all over it. There are a few things we can do. I do not want to leave you with the impression that we are squeaky clean. We are on top of it and I think are now postured to address the more fundamental issue, and that is are we getting everything out of the data we have got.

Senator GORE. Thank you.

Admiral, you were about to address that second question yourself.

Admiral TRULY. Yes.

Senator GORE. So please proceed.

Admiral TRULY. The other two things I wanted to comment on was the complexity of the EOS data problem, which you very correctly pointed out is probably the largest challenge in the EOS system, and also how we are dealing with today's data.

I did enjoy our conversation privately a few days ago on this same subject, and after I came home I did get with J.R. and with Len Fisk and have begun to understand how we do deal with today's data. I believe that we did, that Dr. Fisk did, deliver to your office this morning the list of a number of data sets where we are converting data from digital tape, which I think is good news, where we are taking major sets of science data, converting them from digital tapes into optical disks in a user friendly way so that we can make it easier for scientists to get to that data.

These data sets, some are in work, some are in our plan. And you asked how you could help us. Certainly it would be in support of this data effort in the budget process.

The third of the three things I would like to comment on is the complexity of the EOS, the Earth Observing System problem. It is complex, and the data that we plan to analyze and deal with is literally staggering in its amount. It overwhelms any data analysis that certainly NASA has been in in the past.

But it is necessary because of the complexity of the Earth itself. It is easy, relatively easy, to put up a satellite system that will document what is going on. It is much more difficult to build a model that will predict what is going to go on next year, next decade, 20 years from now. That is the purpose of the EOS system.

This interaction that I mentioned between the lands, the seas, the ice, the atmosphere, and men, and man himself is one that is unbelievably complex, and that is why this huge amount of data is to be gathered.

But it is to be handled by the portion of the EOS program which is called, you may hear it referred to as, EOS DIS, the data information system. That is the reason, that is the very reason that that is the first thing that we are doing on the EOS program, is to bring that data system on line early and to begin to use it, as you pointed out, with today's programs, so that we can begin to learn how to use the data system and be prepared when we get the onslaught of Earth Observing System data later on.

So people have always told me that you should be prepared for the question of, how can I help you? And you asked me. I think the way that you and your committee and the Congress could help the most is to recognize with us that the portion of our budget request that deals with early emphasis on that large data system is most important. It is as crucial as the satellites themselves, probably moreso, or at least as much so, to be supported.

It is going to be a big job. It is going to be a difficult program to manage because no one has ever done this before. But we are excited about it because that is our business. It is our planet. We love to go out to other planets, but we have such a public demand to address the environmental issue in the country, in the world, that I am excited that NASA is going to be a part of it.

But underlying that is our ability to deal with this onslaught of ones and zeroes that is going to be coming down in digital data and to be able to make it user friendly. It is going to be a big job.

Senator Gore. Well, as I have told you before, this is my own personal highest priority, to do what we can in the subcommittee to accelerate the developing understanding of the Earth's climate system, the global environmental crisis, and how we can effectively respond to it.

NASA has the critical role to play, and information management within NASA is the single most important task which must be addressed. We are going to be focusing on that intently, and I will just, for what it is worth, serve notice to you that this will be a subject to which we will return again and again and again until we are satisfied that you are satisfied and that it is in good shape.

I am again really very, very pleased that you are giving it the level of attention that you are now giving it.

I will not pursue that now, but we will return to it shortly in hearings that will be coming up very soon.

Let me shift gears again. The multi-year budget run-out included in the fiscal year 1991 request from NASA indicates that the NASA budget must increase to $17.6 billion in fiscal year 1992,

$19.3 billion in fiscal year 1993, if the proposed program in this request is going to be funded in the coming years.

What annual level of funding would be required by the end of the decade in real year dollars if this program, which includes Space Station, EOS, and Moon/Mars, is approved?

Admiral TRULY. To be accurate, I would like to answer that for the record. But I believe that the run-out in real year dollars of our core program, including EOS, would be at a budget level of about $25 billion per year or so.

Senator GORE. In real year dollars?

Admiral TRULY. I would like to be able to answer that more directly for the record.

But let me also comment about the Moon/Mars. It is almost impossible for me to realistically answer that question because a schedule has not been picked, a mission architecture has not been picked. We did do a 90-day study that looked at some notional ways we could do it the way we know to do business in the past.

But it is hard for me to project what would be required because we do not have a program at this point. What we are asking for in this year is technology money to get started. And so I am not trying to avoid that question. I just cannot really answer it properly.

[The following information was subsequently received for the record:]

Approved estimates of NASA's funding requirements are not available past FY 1995. In FY 1995, the required funding level to accomplish the program proposed in the FY 1991 President's budget is $21 billion. This includes funding for the ongoing program as well as the Earth Observing System and the Space Exploration Initiative.

Senator GORE. Well, the program includes a permanent base on the Moon and a base on Mars, correct?

Admiral TRULY. That is right, a science outpost or research outpost on the surface of the Moon and then later a manned exploration to Mars.

Senator GORE. And a base on Mars?

Admiral TRULY. Eventually, in the long term, yes. In our looks, we never spend a great deal of time about the implications of that since it would be halfway into the next century or a third of the way into the next century before that base would become a reality.

Senator GORE. Does NASA have preliminary cost estimates or a range of cost estimates for the Human Exploration Initiative, which includes the lunar base and expeditions to the surface of Mars by people?

Admiral TRULY. We made the estimates in the 90-day study that we did last fall. I think they are unreliable if you wanted to use them as an actual cost because it is not the program that we would use. We had not laid out an architecture.

But in gross terms, what those studies showed, that in order to emplace a research outpost on the surface of the Moon starting from now would take about $100 billion. Now that is hard to, and impossible as a matter of fact, to be precise about.

Senator GORE. Before you go on, could you add to that what the estimate is for then going in the same program to Mars?

Admiral TRULY. Yes. Then, if I remember the numbers correctly, the Mars leg of that particular reference approach took about another $150 billion. But this was spread out well into the next century.

Senator GORE. What other elements in addition to that $250 billion were included in your initial estimates?

Admiral TRULY. The other thing that we looked at was the maintenance of the research outpost on the Moon, which naturally requires a continuing replacement of equipment and science and people as the decades go on. So as long as you want to run out the program, you can run out costs.

Senator GORE. What did you run them out to? What was the estimate?

Admiral TRULY. Basically, the way we looked at them was on an annual basis it would require a NASA about twice the size of today's NASA to do the job as the years go on. As you know, so if you pick your year in the future then you can put a number to that.

But that particular approach would require a huge investment on the part of the nation.

Senator GORE. Well, if I could short-circuit, shortcut, your response a little bit, I understand why you are reluctant to add it all up and give us that figure. But the figure included in your preliminary estimates was about $450 billion, correct?

Admiral TRULY. By the time you are well into the next century, and to an approach that is not our baseline.

Senator GORE. It would not be realistic to fund that through additional dredging fees of the Corps of Engineers, would it?

Admiral TRULY. Now, that is a macroeconomic issue.

Senator GORE. You are right, you are right. That is a macro issue.

What is not funded in the multi-year budget run-out that you consider vital to the implementation of NASA's mission? Before you respond, let me give you a couple of specific questions, a few specific questions to flesh out the broad question.

Are there any funds for Earth probes beyond TOMS and Scatterometer in the fiscal year 1991 budget request?

Admiral TRULY. No. It would require moneys beginning, I believe, in 1992.

Senator GORE. Is there any money in the request for an assured crew rescue vehicle?

Admiral TRULY. There is money in the request for a phase B definition for the assured crew rescue capability, which is a lifeboat to make sure that the people aboard Space Station have an assured way to get home. There is not money in the 1991 budget for the development phase of the program, which will be addressed as a part of the 1992 budget.

Senator GORE. Are there any new starts in space science besides the Lunar Observer and Lifesat?

Admiral TRULY. No.

Senator GORE. Is there any money for development of heavy lift launch capability, such as a Shuttle C or a new advanced launch system, or for a new Space Shuttle Orbiter?

Admiral TRULY. No, there is no development money for the heavy lift system. There is money that would be applied to both continue to look at the advanced launch system and Shuttle C, but there is no development money. And no, there is not money for a new Orbiter, and that also will be addressed by me internally and then potentially with the Congress in the 1992 request.

Senator GORE. Any funds for the global change technology initiative or a high-performance computing initiative?

Admiral TRULY. No. The global change technology initiative is a technology program that our people would like to do for the next generation of global change, sensors and so forth, and there is not money in there. That will be addressed in 1992.

The same is true in the President's request for the high-performance computing initiative.

Senator GORE. You say the President's request. There is no request for money for that at NASA.

Admiral TRULY. Maybe I misspoke. I said in the President's request in the 1991 budget there is not money for the high-performance computing initiative.

Senator GORE. Okay. Just as an aside there, the President's science advisor testified last week, earlier this week, that the high-performance computing initiative should be regarded as the single most important step America could take to improve our economic competitiveness and our proficiency in science and technology.

Admiral TRULY. If I might add, Dr. Bromley has taken the lead within the White House, and I have personally been to a couple of meetings with him and others on this specific point, to pull together a crosscutting agency proposal as to how to deal in future budgets with high-performance computing.

Senator GORE. We know. We have had a series of hearings with Dr. Bromley on that question. That is another of our highest priorities in this subcommittee.

Are there any funds—but there is no money in the budget request for NASA, even though it is the highest priority for the country in the view of the President's science advisor, and many others, I might say.

Are there any funds for the assured shuttle availability program to upgrade the shuttle's performance, safety, and reliability?

Admiral TRULY. I want to be careful how I answer this, because I view—we tried what I would call a budget management approach and presented it to the OMB, called the assured shuttle availability, which was to put into our budget a line item that would give us more stability in future years as we develop new brakes, new computers, new hardware for the Space Shuttle, which I think is absolutely mandatory.

The specific answer to your question is no, there is no money against that line item. But I want to be quick to point out that there is money for individual improvements that would have been folded into such an initiative, assured shuttle availability. And we intend to discuss this with OMB again next year.

Senator GORE. All right, very good.

Let me turn now in a little more detail to the Human Exploration Initiative, which we started talking about earlier. Last Friday the National Research Council released its assessment of NASA's overall plans for a lunar base and an exploration to Mars. This is the first of two outside reports requested by the National Space Council.

What is your reaction, Admiral Truly, to the National Research Council report, and does the Council's finding that the NASA plan appears reasonable in technical terms please the agency? Or what other reaction do you have to it?

Admiral TRULY. Well, again I think I would like J.R. to give you his personal view. But my view is that I was delighted. It was an excellent group of people that looked at our 90-day study. They recognized that any study that takes 90 days to go back to the Moon and to Mars is going to have shortfalls, and we did also.

But in the end they said that the study was prudent, that it was well laid out, that it recognized the need for new technologies. And so in general I read over it and I liked what I saw.

I also met with Dr. Stever, who was the head of the group, for about an hour with J.R., and we talked through their major findings, and I came away from it feeling good.

Incidentally, I must say that I think that NASA has benefited over the years by inviting the National Research Council to look at our programs. I think it is a normal way of our doing business, and the fact that they did the study was not only normal but good and very necessary.

Senator GORE. If they had come out with different kinds of conclusions, you might not feel quite as warmly about it.

Admiral TRULY. Well, as you know, after the Challenger accident I probably got more help than anybody in town on oversight of what we were doing. And frankly, some of it was excellent and some of it was less than excellent.

But in the case of Dr. Stever, who ran the oversight over a period of three years as we recovered the solid rocket motors, my hat is off to him individually and to the group he led at that time and to the study that he put together here.

Senator GORE. Very good.

Admiral TRULY. I have the highest regard for his advice.

Senator GORE. Well, very good.

Besides the seven technology areas that were outlined in the NASA 90-day report as being critical to implementation of the Human Exploration Initiative, did the Stever panel also recommend that NASA do additional technology activities in the areas of artificial gravity and the human-machine interface?

Mr. THOMPSON. Yes, I think they did. They encouraged us to look in those areas and disciplines as well.

Senator GORE. All right. Does the Stever report also indicate that a nuclear propulsion system is a critical element and pacing item of a manned voyage to Mars?

Admiral TRULY. They did emphasize what they thought would be important investments in nuclear power and in nuclear propulsion. We had also recognized that in our 90-day report, but had not made—in our 90-day report, we concluded that in fact you could go to Mars without nuclear power, but nuclear power would probably make the trip actually cheaper and certainly much shorter and therefore less risky.

Senator GORE. All right, very good.

What other comments does the Stever report make about additional space transportation system technology development activities?

Admiral TRULY. They emphasized the investment in heavy lift vehicles and in new ways of doing space transportation less costly. And I believe, as I recall from memory, I believe that transportation was, in their priorities, was second only to life sciences research. So that investment got a very high recognition in our report as well as their review of our report, and I might say for other people that have looked at the potential of an exploration program.

Senator GORE. Would I be correct in interpreting this report if I said that there is a requirement for an extensive technology program before the architecture, timing and cost of the program itself can be established and before the human and technical risks can even be determined? Is that essentially what the report said?

Admiral TRULY. I think that those of us, both in NASA and the Space Council and the industry people we have talked to and the NRC, all have agreed that the first thing to do is to take a look at technologies that can then allow a program to be developed.

That is why in the fiscal year 1991 budget you do not see a request for spaceships and particular vehicles. You see a request for investments in technologies and new materials and robotics and automation and so forth, that will allow that program to take shape.

Senator GORE. Would I also be correct to interpret the report to say that the pace of the Human Exploration Initiative will be determined by non-technical constraints, such as the sustainable level of resource commitment and the acceptable level of risk?

Mr. THOMPSON. That was very clearly made a point in the report, and we spent a lot of time talking to Guy about that. I think, given the technology investment up front, we are going to have the technical know-how to do it, but it is going to take a sustained commitment throughout the country for decades to pull it off. And certainly that was highlighted in the report.

Senator GORE. What was the reaction of the National Research Council to the Lawrence Livermore Lab proposal that had been billed as a cheaper, faster, better way to implement the mission?

Admiral TRULY. Well, I think it would be more appropriate if I let their report stand on its own merits. But as I recall the summary that Dr. Stever gave to us, they thought, as I did incidentally, that the ideas proposed by Lowell Wood and the Lawrence Livermore organization were a lot of very interesting technology ideas; however, there was an underestimation of the difficulties in putting together a large system, both in budget and schedule.

Senator GORE. A very kind choice of words, Admiral Truly.

Dr. Wood has an active imagination on many programs. I respect his level——

Mr. THOMPSON. I think the way Guy summarized it to us is that, certainly you have taken a conservative approach and that is because you have been there and others have not. And I think that explains a lot of the thinking that was in their report that reflected some of our early ideas. We were quite pleased with it.

Senator GORE. Admiral, as a former astronaut would you give us your reaction to making this mission in an inflatable spacecraft?

Admiral TRULY. Could I provide that for the record?

We have looked at inflatables in NASA years ago, and it gets down to how reliable and safe you can make them, and we do not know how to do that right now.

Senator GORE. My kids cannot even make them work in the swimming pool. They are not very reliable there.

But anyway, in what ways does the National Research Council report influence the proposed technology initiative, exploration technology, that NASA has submitted to the committee? And what I am leading up to in the follow-up question—I will telegraph it for you—is a question about whether or not NASA will ask for realignment of this request in light of the findings of the Stever report.

Admiral TRULY. Of the 1991 request?

Senator GORE. Of the exploration, the proposed technology initiative, exploration technology.

Admiral TRULY. No, I personally do not see any realignment required. There is going to have to be a continual and ongoing look at how to apply those technology moneys, but nothing that Dr. Stever in his report signaled, to me at least, that we were doing the wrong by getting started with technology that can pay off, both for this mission and, I might add, as you know, in many parts of our society.

New materials and robotics technologies will have applications in ways we do not imagine here on Earth.

Senator GORE. Another couple of brief questions on the Moon/Mars initiative. I was looking at the funding table. There is only $188 million in new money for this initiative. That is the total amount, correct?

Admiral TRULY. That is correct.

Senator GORE. Am I also correct that the Moon/Mars funding is spread within the following accounts? And I see Mr. Campbell has his tables ready there. Space Station, $20 million for transition definition. You said that earlier.

Space transportation capability development, $50 million?

Mr. CAMPBELL. That is correct, Mr. Chairman.

Senator GORE. Mars Observer, $15 million?

Mr. CAMPBELL. That is correct.

Senator GORE. Lunar Observer, $15 million.

Mr. CAMPBELL. That is correct.

Senator GORE. Life sciences, no increase.

Mr. CAMPBELL. That is correct.

Senator GORE. Space research and technology, $88 million.

Mr. CAMPBELL. That is correct.

Senator GORE. That is the total. Am I to assume that the advanced launch system and the Aero-Space Plane are now part of the Moon/Mars initiative?

Admiral TRULY. No, I would not phrase it that way at all. When Mr. Darman at OMB put together the President's budget book, it was decided to, on certain large programs, to take what I would call a cross-cutting approach and show all those programs that would have some direct influence on the Human Exploration Initiative and also, I might add, on the global change.

In other words, in those aggregate numbers you can find what all the agencies are spending that would have an application. But the advanced launch system, your specific question, and the National Aero-Space Plane have been justified and have reasons for existence in the technology and research area totally apart from the Human Exploration Initiative.

So I would not describe them as being totally a part of it. They certainly will be integral to the success of it, I think.

Senator GORE. Well, according to that table you referred to, OMB may be guilty of a serious tactical error in including all this stuff under Moon/Mars. The fiscal year 1991 request includes $1.3 billion for Moon/Mars. However, OMB has required an inappropriate packaging of many ongoing programs in NASA and other Federal agencies under this heading.

I think that is a potentially grave tactical problem, as the Congress experiences these growing budget pressures and people look at that category, $1.3 billion for a permanent base on the Moon and a mission to Mars, and people come to the mistaken conclusion that that is what it is and see that as an opportunity to accomplish savings in that amount, when actually only $188 million is in your budget request for Moon/Mars.

But all of the ongoing programs in NASA and in the other agencies which OMB has labeled "Moon/Mars" it seems to me are in some measure of increased jeopardy if somebody flies over that budget at 10,000 feet and just looks at large categories with an eye to seeing where some tough choices can be made.

So I wanted to highlight that for our hearing here today.

Admiral TRULY. If I might respond very briefly. I appreciate your focusing in on that issue. I believe that it was thought that it would be helpful to aggregate the numbers so that people would understand those programs that would contribute.

But you are absolutely right, the amount of new money that is not in the NASA core program that is being requested is $188 million in fiscal year 1991.

Senator GORE. Well, we have some other questions for the record, Admiral Truly and Mr. Thompson and Mr. Campbell.

I think we have had a good discussion here this morning. From my standpoint it has been. I have learned a lot and always enjoy having a dialogue with you, and I enjoyed the opportunity to get into a little detail with you. I look forward to continuing this discussion here in this format and in private discussions that are ongoing.

I wish you well here at the beginning of the budget cycle. We will work with you closely. I think I can speak for every single one of my colleagues on this committee saying how much confidence we have in the management team that you have assembled there at NASA now.

As you know—I will speak only for myself in this comment—I had not always felt exactly that way. I have always had great respect for the individuals. I have sometimes had questions about the way in which NASA was being managed. I do not have those questions now.

I think that you have really got a great team there and the problems really are ones that we and your team can work together to try to cope with, these larger contextual problems of how we are going to define the missions, how we are going to pace the funding, how we are going to justify the funding, how we are going to help identify the sources for doing what needs to be done, and how, in the example of the Mission to Planet Earth program, how we can speed up the acquisition of answers so critically needed, in the case of Moon/Mars how we can get the technology development process successfully started, to give us an opportunity to define that mission and make a very careful set of choices when we have all the information available to us about how feasible this is, what the risks and so on, what the resources requirements are, and third, how we can work together to make sure the ongoing programs are not crippled through the process of cannibalization, that is taking too much money from them for these worthy new starts that we all would like to see got off the ground.

But in closing, again thank you for the amount of time that you have spent with us here today and for the amount of time and energy that you put into this on a daily basis. I know you are away from home a lot. You work very hard and we appreciate that.

The country appreciates the sense of mission which you have reestablished at NASA, the dedication which I think is so evident in the agency. We appreciate you on a continuing basis.

With that, we will adjourn today.

Admiral TRULY. Thank you, Mr. Chairman.

[Whereupon, at 11:31 a.m., the subcommittee was adjourned.]

NASA SPACE SHUTTLE/SPACE STATION

WEDNESDAY, MARCH 28, 1990

U.S. Senate,
Committee on Commerce, Science, and Transportation,
Subcommittee on Science, Technology, and Space,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:43 a.m. in room SR-253, Russell Senate Office Building, Hon. Albert Gore, Jr. (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORE,

Senator Gore. The Committee will come to order. I apologize to our witnesses and guests for the delay in our starting time. It was unavoidable because of meetings called by the leadership and other committees that were rescheduled as a result.

Today, this subcommittee is going to focus its attention on the Administration's budget request and the current status of Space Station Freedom and the space transportation system programs, both of them within NASA's Office of Space Flight.

This is an ambitious agenda for one day, but it is ground we must thoroughly cover before we can proceed with confidence on legislation authorizing funds for the coming fiscal year for NASA's space programs.

NASA has requested significant increases over current funding levels to continue preliminary design work on the space station, to support planned increases in the number of shuttle flights, and to continue development of the new advanced solid rocket motor. In my view, these projects are all extremely critical to our nation's efforts to maintain our preeminence in space, and all are important in our efforts to enhance the competitive position of the United States in the international marketplace, to attract the youth of our country into the sciences, and to develop critical new technologies for the 21st century.

I have long been an avid supporter of the Space Station program. I still am. However, in the past week the attention of the public has been keenly focused on the potential for a major disaster in the Space Station Freedom program. I am speaking about the ongoing NASA study of external maintenance on the space station, which has caused many to conclude that, as currently designed, it cannot be built.

The fear is that even before construction is complete record numbers of manned space walks will be necessary to perform needed maintenance. Specifically, this report has identified the need for more than 2,200 hours of extra vehicular activity in the dangerous environment of space, this in spite of the fact that we have only had 400 hours of experience with astronaut space walks in the entire 30-year history of the American space program.

This new study indicates that we will require many times that total just for maintenance of the space station.

While I realize that NASA's current review is a normal part of the development of any new project, these preliminary findings give me cause for great alarm. Very simply, the Space Station Freedom is in jeopardy until we gain a more complete understanding of NASA's process for designing the space station, when and how the EVA issue will be satisfactorily resolved, and, perhaps more importantly, whether or not NASA has adequate control over this $30 billion project.

I intend to carefully question the three astronauts who are leading this review, focusing on the safety of EVAs, their thoughts on the need for a new space suit, a new emphasis on robotics, and what alternatives are available to NASA in order to minimize the astronaut space walks.

Of course, because we are considering legislation to provide funding for NASA, we must cover much more during this session. This year, as with every other, we will conclude in a battle over the allocation of scarce funds. That battle may be even tougher this year than it has been in past years. Reductions in funding will adversely affect the time frame and content of the space station, as well as the efforts of NASA to safely handle the number of planned shuttle launches during the coming years.

Accordingly, we must build a record today that will justify our efforts to ensure continued progress in the space program.

With that, let me turn to my colleague, Senator Kasten, for any opening statement he might have, and then we will welcome our first panel of witnesses.

OPENING STATEMENT BY SENATOR KASTEN

Senator **Kasten**. Mr. Chairman, thank you.

Mr. Chairman, we are holding this hearing to explore in more detail NASA's Space Station and Space Shuttle Programs at a time of some recent controversy in regard to the Space Station.

We see the Administration requesting $2.5 billion for the Space Station for FY91, a 40 percent increase over last year's amount. But, we also have the NASA investigative panel, headed by Dr. Fisher and Mr. Price, stating that the Space Station could not be built according to current design because many of the components would start to fall apart before the Station was completed.

I am pleased that we have both Dr. Fisher and Mr. Price scheduled to be here today.

I will be interested in hearing not only NASA's response to the study group's concerns, as expressed by Dr. Lenoir, but also from those accompanying him.

Those of us who are supportive of NASA, the Space Station, and the other missions, all costing significant sums of money, have to be willing to accept criticism—especially that coming from within NASA itself.

How can we not be concerned by estimates of 2,200 hours of spacewalks annually just to keep up with repairs and maintenance. Though Administrator Truly has dismissed the report's concerns as "unrealistically pessimistic", it will be necessary for us to explore the basis of the report's findings. Often where there is smoke there is fire, but just as often the truth often lies between the two extremes. That is what we have to sift out here.

I look forward to today's witnesses and pursuing this matter with you and the subcommittee, Mr. Chairman.

Mr. Chairman, I am going to be in and out of this hearing during the day because of some other responsibilities, but I think it is important to recognize that the testimony today is going to be key in terms of what both the authorizers and the appropriators are going to be doing with this overall program. I have been a strong supporter, and I expect that I will continue to be a strong supporter of the Space Station. To that end, I am pleased to see the Administration requesting $2.5 billion for FY91, a 40 percent increase over last year's Appropriations level. But a number of the concerns raised by this study obviously are of great interest to a number of us in Congress.

Thank you, Mr. Chairman.

Senator GORE. Thank you very much.

Dr. William Lenoir is the Associate Administrator for the Office of Space Flight at NASA, and is accompanied today by Mr. Richard Kohrs, Director of the Space Station Freedom Program, also in the Office of Space Flight; Mr. David Walker, who is an astronaut with NASA; Dr. William F. Fisher, an astronaut with NASA; and Mr. Charles R. Price.

We welcome all of you here. We are going to have questions for all of you. You are invited to make statements at this time. I understand, Dr. Lenoir, that you do have a statement. Without objection, your full text will appear in the record and you are invited to present a summary as you see fit. You are recognized at this point for that purpose, and we want tp welcome all of you. Please proceed.

STATEMENT OF DR. WILLIAM B. LENOIR, ASSOCIATE ADMINISTRATOR FOR THE OFFICE OF SPACE FLIGHT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY RICHARD H. KOHRS, DIRECTOR OF THE SPACE STATION FREEDOM PROGRAM; JOSEPH B. MAHON, DEPUTY ASSOCIATE ADMINISTRATOR FOR FLIGHT SYSTEMS; CAPT. ROBERT L. CRIPPEN, DIRECTOR, SPACE SHUTTLE PROGRAM; MICHAEL B. MANN, DIRECTOR FOR RESOURCE MANAGEMENT; DAVID M. WALKER, ASTRONAUT; DR. WILLIAM F. FISHER, ASTRONAUT; AND CHARLES R. PRICE, ASTRONAUT, CHIEF, TELEROBOTICS SYSTEMS BRANCH, JOHNSON SPACE CENTER

Dr. LENOIR. Thank you, Senator. I would like to make a short statement and submit our statement for the record.

My understanding is that I will make our short introductory statement and then we will deal with the space station EVA issue, at which time we will pause briefly so we can relocate some people here and then continue with the rest of what I would consider the hearing for our fiscal year 1991 budget. Is that correct, sir?

Senator GORE. That is the way we planned to proceed, yes.

Dr. LENOIR. Okay, fine. That is the way we had planned.

What I would like to first do is to remind us all that the Office of Space Flight is a large part of NASA. It includes the space shuttle, the space station, expendable launch vehicles, upper stages, Spacelab, a series of advanced programs, and, on my list last but certainly not least, our institution. That includes the Johnson Space Center in Houston, the Kennedy Space Center in Florida, the Marshall Space Flight Center in Huntsville, Alabama, and the Stennis Space Center in Mississippi, as well as the headquarters part. That is a very important understanding.

You have introduced some of the people that will be up at the table this morning, and I would like to just briefly mention the others. Robert Crippen—Bob, if you would wave your hand—is the Director of the Space Shuttle Program and will join us shortly; Joe Mahon is the Director of our Flight Systems Program, and he will join us later. Mike Mann, sitting on my right, is the Director of our Resources Management, and his job is to keep me from saying anything dumb with respect to the numbers this morning.

As you noted at Admiral Truly's hearing here, that was the last opportunity you had to have Marty Kress sitting behind you. I would like to welcome Marty to this side as the first opportunity for him to sit here and to assist us. We understand more and more every day how much you must miss him.

Senator GORE. Everything has changed now, though.

Dr. LENOIR. We understand, accept, and will do our very best to discharge the tremendous responsibility that is laid on us to intelligently and wisely spend the nation's money on the programs that we have.

I would like to review our accomplishments over the last year. Since return to flight, we have flown nine space shuttle missions. Next month we will fly the Hubble Space Telescope mission, and the month after that we will fly an Astro-scientific mission. STS-31, or Hubble, is tentatively scheduled on the 12th of next month. We will have the flight readiness review Friday-Saturday of this week. We are looking at possibly pulling that launch date forward one day. With Hubble, that will be five flights in seven months, as we expand our flight rate.

Our expendable launch vehicle record. We have completed the NASA ELV operations, if you like, and have begun our transition into commercial operations.

On the space station, we have made significant progress toward first element launch, and we are still on schedule. Over the past year we have gotten one year closer to the beginning of the program.

I wanted to emphasize that as we move to the preliminary design phase of the program the space station moves from a phase where its product is paper, reports, et cetera, to one where it is increasingly hardware. I have a handout that should be in front of you that is photographs of hardware developments within the program.

The first four are in the environmental control/life support area in Huntsville that look very much like a chemical factory. The emphasis is that we do have hardware. We are doing experiments. We are learning. We are changing the design. And it is solidifying and it is all on schedule. I am not going to thumb through each and every one, but I wanted to emphasize that we are into hardware.

We have a stable baseline and a stable management team. From the space station point of view, both Dick Kohrs and I are here today to tell you at the end that we will see you again next year personally.

We have within our systems engineering function begun the difficult resource allocation. We have allocated weight and power and a reference assembly sequence, and we have the allocation of EVA in work, which will be our special topic later.

Our strategy is to maintain our manifest, to fly our eight flights in fiscal year 1990, ten in 1991, 11 in 1992. Each flight tends to be more complicated than the flights before the Challenger accident. We no longer have the simple deploy missions; we have more scientific missions, more Spacelab missions.

We will complete the transition to the mixed fleet. To that end, we have developed a flight assignment board that I chair that takes each and every payload that NASA is responsible for delivering to orbit and manifesting it first on an expendable launch vehicle, unless it requires the presence of human beings, some unique attribute of the space shuttle, or there is some other compelling reason, such as national security or international relations. Otherwise, it is on an expendable.

We are planning major enhancements to the shuttle. Main engine enhancements. The advanced solid rocket motor we have discussed. I am pleased to report that on Friday of last week, at 9:00 p.m., we signed a memorandum of agreement with the prime contractor, Lockheed, and the final contract is being prepared. We expect that to be signed and fully executed by the middle of April. And the extended duration orbiter.

On space station, we plan to hold schedule. First element launch is in March of 1995, and we are holding that. We must stay on top of our requirements management and hold tight to the requirements from both a cost and a schedule point of view.

We will be paying more attention to affordability and the role of life cycle cost. We have to not only build a space station, but build one that the country can afford to operate.

In international integration, we will be working within our operations to ensure that we have a true partnership.

Finally, we will be working to ensure early and continuous utilization of the space station. We will continue the development of complementary systems such as the shuttle station integration and its docking and berthing systems, and the orbital maneuvering vehicle, which is an enabler necessary for our infrastructure and to support the Hubble Telescope and the AXAF programs.

We will be developing a strategy for our capability expansion, the assured crew return vehicle, the next orbiter, Shuttle C, advanced launch systems.

Specifically, in fiscal year 1990 that we are currently in and approximately half through, and fiscal year 1991, the budget in question, our plans are to continue our programs. Our budget increase is largely mandatory, based on planned growth, more missions, more complicated missions, the transition of the advanced solid rocket motor into its full-scale development. New content is minimal. It is a continuation of our programs, even though it results in more money.

We support the January 1990 manifest with shuttles, expendable launch vehicles, upper stages, Spacelabs, and, beginning in 1995, space station supports it as a payload.

There are many areas of other increases that were necessary. I will only mention a few. The prices of ammonium perchlorate and rayon in our space shuttle program have gone up significantly. We have run into some technical difficulties on our alternate turbo pumps that will cost more money, but we are moving along.

We have spent some money to upgrade the launch processing system that has needed that effort for quite some time. We have money in fiscal year 1991 proposed for phase B on our assured crew return vehicle and several other areas.

Space station will grow as planned, the focus being our preliminary design review. Following the preliminary design review in December, we will expand into the detailed design, leading to the CDR two years hence. We will continue shuttle tests of technology, thermal experiments, EVA experiments, and so on, and we will continue our facilities development to be ready not only to begin construction in 1995 but to begin actual utilization in 1996.

What are our challenges and concerns for the coming year or year and a half? Our institution, our research, as we call it, and program management, our people. The appropriations realignment has affected us in ways that has made that very tight, and our institution is strained to the breaking point.

We worry about shuttle system obsolescence and we are working to plan to use the space shuttle past 2010. We must protect our ability to produce orbiters. In the space station, the primary concern is funding adequacy and stability. It must not only be there, but it must be stable.

Our PDR completion schedule is aggressive and we must stay on top of it and manage it. Systems integration becomes more and more important; our special topic is an aspect of that. Resource control will also require significant management attention. That is also the subject of our special topic. We have recently assigned allocation controls on power, weight and volume, and I mentioned the assembly sequence, and today we will discuss the EVA portions of that resource control/resource allocation.

If I might, let me take a few minutes and discuss the space station EVA concern. First, I would like to put it into focus and talk not just about the Fisher-Price part but how it fits and what the overall engineering and integration process is, of which this is but one of six steps.

We began at the beginning of the program with a top-down assessment, if you like, management looking at the concept, looking at what was taken to be available, and allocating extravehicular activity to the program. At that time, we said that we were comfortable with three EVAs per week.

Subsequent studies, again from the top-down perspective, lowered that to one EVA per week, which is our current baseline. Dick Kohrs and myself, the station management, are not comfortable with one per week. We have set a goal of one per month that we think we can attain.

The second step is a bottom-up review. As the design matures and we begin to have not just paper concepts but real design, we can look at how does it work, how does it break, how will it require maintenance, and, from the bottom-up, build the requirements, add them together, compare them to the top-down. Not unlike our budget preparation process, we expect the bottom-up to be high and not in line. And then we go challenge it. We will talk more about that bottom-up process that Bill Fisher and Charlie Price have worked.

They will identify the requirements for external maintenance and options for dealing with it, both simplifying the EVA and non-EVA answers. Following that, we will begin a systems integration of what I call iterative interaction with the individual designs. That will result in a concept for how to deal with it and derive the requirements for EVA, for the flight telerobotics servicer, for reliability, for orbit replacement unit interfaces, orbital replacement unit locations. Maybe we do not like it outside; we will bring it inside.

The preliminary design review itself will review all of those inputs and the designs from the projects and subsystems and will result in the development of a preliminary external servicing and maintenance plan. It will result in the development of a preliminary EVA operations plan, preliminary design for the flight telerobotics servicer, the Canadian counterpart, individual ORUs, reliability location interfaces, et cetera, and preliminary integrated logistics support plan.

Following the PDR we will go through another two-year iterative interaction phase as we go into the detailed design. This will culminate, coming out of the critical design review, with the baseline external servicing and maintenance plan. We will talk more about the second step as we go through answering your questions.

The program view is there is no fatal flaw in the space station program. The issue that we are dealing with is not only workable but it is workable in scope, within our proposed cost and on our proposed schedule. What we read in the newspapers notwithstanding, there is no division within NASA. NASA headquarters has no issue with the results of the study nor the people doing the study. We commissioned it. We are not even surprised by the results. We stand behind it. We are proud of the results to date, and far from trying to sweep it under the rug we want it to go on to completion in July so we can begin the third step of this phase.

There are alternatives to EVA and that is one of the things that we have asked Bill and Charlie to identify for us, alternatives such as robotics. We have a flight telerobotics servicer. We have a Canadian special purpose dexterous manipulator. We can go back and increase reliability on individual boxes. We can relocate them, if they are troublesome, inside perhaps. We can simplify our EVA by spending some money to make it easier, by building the tasks to be uniform and standard, by building them to be, as we call it, EVA-friendly, and we also want to build them to be robotic-friendly.

We can simplify our EVA overhead, potentially eliminating some of it with robotics and paying attention to our primary lessons from Skylab, where we learned that training and proper restraints are the two biggest requirements in extravehicular activities.

The people that are here today to deal with this, you have met Dick Kohrs and you have met Dave Walker from the Astronaut Office. Dave is leading our study in the assembly. Dave is not actually part of the Fisher-Price study, but since it relates to it, we asked Dave to be here in the event that there are questions on the assembly process.

Bill Fisher, also an astronaut, like Dave on detail from the Astronaut Office to the project office to work this issue, and Charlie Price, who is the Chief of our Telerobotics Systems Branch at the Johnson Space Center, have begun the study. We will answer your questions.

But I would like to put one thing into context, and that is that as we look at this we must realize that when we assign tasks, as we will at the PDR, to the telerobotic servicer, that is really but a beginning. We will do what we can. We are limited by our current knowledge and our current funding, but we will continue to grow. We will continue to infuse new, updated technology into our telerobotics activities, artificial intelligence technologies and, as time goes, we will work to back EVA out more and more and to push the robotics development for, among other reasons, to serve as a good point of departure for our exploration issues.

Thank you for the opportunity to make this statement and we would be pleased to answer your questions.

[The statement and questions and answers follow:]

Statement of

Dr. William B. Lenoir
Associate Administrator
Office of Space Flight
National Aeronautics and Space Administration

before the

Subcommittee on Science, Technology and Space
Committee on Commerce, Science and Transportation
United States Senate

Mr. Chairman and Members of the Subcommittee:

As I review our FY 1991 budget, I hope to convey the spirit of enthusiasm and purpose which permeates the Office of Space Flight. We enter this new decade with new leadership and renewed determination. We look forward to a future of technological achievement, economic growth and opportunity, and reassertion of United States leadership and preeminence in space. So it is with great pride and optimism that I report to you today on our fiscal year 1991 budget objectives.

As you are aware, space flight is unforgiving of error. Accordingly, we are extremely proud of our launch record. In January Columbia successfully deployed the SYNCOM-IV satellite and retrieved the Long Duration Exposure Facility on a flight of record-setting duration. Atlantis accomplished a classified Department of Defense mission in February. Early next month Discovery is scheduled to carry the Hubble Space Telescope to orbit. It will be our fifth launch in seven months — an achievement which testifies to the Shuttle program's steady and deliberate buildup of its flight rate. Also during 1989, we flew two successful Expendable Launch Vehicles (ELVs) and three upper stages. A great deal of behind-the-scenes efforts in many diverse areas contributed to these launch successes. The sum of these is far too complex for detailed discussion in this forum, but the thousands of working men and women in government and industry who share in this accomplishment deserve our warmest commendation.

Space Station Freedom program activity during 1989 included extensive tests on hundreds of hardware items in all four work packages. Accomplishments ranged from activation of the Environmental Control and Life Support System (ECLSS) comparative testbed and testing of all the ECLSS subsystems, to initiation of solar cell production for the photovoltaic power system. We have begun the ambitious series of system-level Preliminary Design Reviews (PDRs), and anticipate completion of the program-level PDR in December — a milestone of great significance. Also during 1989 we completed an extensive design phase revision which produced a more streamlined, cost-efficient program. The program has also benefited from the infusion of experienced managers from the Space Shuttle program. Finally, an organizational realignment has brought the Space Station and Space Shuttle programs closer together to assure their harmony, and installs more explicit lines of authority and responsibility. Our working relationship with the international partners has been strengthened by day-to-day communications at the working level of the program, complemented by frequent meetings between our respective program managers and directors.

SPACE FLIGHT FY 1991 BUDGET REQUEST

We are resolved that this budget be dedicated to sustaining the safety and mission success which we presently enjoy, and to moving forward toward the challenges and opportunities which await us. I shall discuss the highlights of this budget in the context of our resolution to achieve the proper balance of ardor, prudence, and fiscal responsibility.

The Office of Space Flight's FY 1991 budget request includes $4,420.6 million under the Space Flight, Control and Data Communications (SFC&DC) appropriation, and $3,224.3 million under the Research and Development (R&D) appropriation; $773.4 million for Space Transportation Capability Development, and $2,450.9 million for Space Station. In FY 1990 our corresponding budget is $3,580.5 million in SFC&DC, $562.4 million in Capability Development, and $1,749.6 million for Space Station. In addition, our current budget plan for FY 1990 includes a $175 million undistributed reduction in SFC&DC as the result of appropriation actions. The agency plans to resolve this unfunded requirement later in the year. Additionally, Space Station's funding request includes a three-year advance authorization and appropriation that would provide $2,906.9 million in FY 1992 and $3,031.3 million in FY 1993. Multi-year funding is necessary to greatly increase programmatic stability, provide continuity of the development process, and protect the integrity of our commitments. This request is consistent with the proposed development cost ceiling of $13,000 million in 1984 dollars.

With this FY 1991 budget level and its runout, we support buildup of the Space Shuttle flight rate to 12 flights per year beginning in 1994, the buildup of flight activity for ELVs, a related increase in payload support activities (primarily in Spacelab and Payload Operations), and the buildup in the Advanced Solid Rocket Motor (ASRM) program as it begins its first full year of development. The FY 1991 budget also supports an increase in propulsion technology development activities for the President's Human Exploration Initiative. The SFC&DC request is divided into two elements — $1,302.0 million for Shuttle Production and Operational Capability, and $3,118.6 million for Space Transportation Operations. The R&D request is divided into two elements — $2,450.9 million for Space Station and $773.4 million for Space Transportation Capability Development.

Programs and activities funded under these categories are:

- SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY — provides the capability to fly safely at the projected flight rates. Funding is provided for Orbiter Operational Capability, including the Extended Duration Orbiter and Structural Spares; Propulsion Systems, including the

Advanced Solid Rocket Motor (ASRM); and Launch and Mission Support.

- SPACE TRANSPORTATION OPERATIONS -- supports procurement, processing and services to the mixed fleet launch capability. Funding is included for Shuttle Flight Operations, Shuttle Flight Hardware, Shuttle Launch and Landing Operations, and commercial ELV launch services.

- SPACE TRANSPORTATION CAPABILITY DEVELOPMENT -- provides for effective use of and extensions/improvements to our operational capabilities. Funding is included for Spacelab development and operations, Upper Stages for both Shuttle and ELVs, the necessary Engineering and Technical Base (ETB), Payload Operations and Support Equipment, studies of new capabilities including Advanced Programs and Advanced Transportation Technology (such as Shuttle-C, Heavy Lift Launch Vehicle, and Human Exploration Initiative), Tether Satellite System, and the Orbital Maneuvering Vehicle (OMV).

- SPACE STATION -- requirements for FY 1991 and the following two years reflect the progress made in the development program. The detailed design phase of the program begins in FY 1991 and development hardware fabrication and testing activities must accelerate accordingly to support Critical Design Reviews in the following year. Also, key ground facilities required for testing, training, integration, and control must be completed in order to support the Station schedule. The request supports planned growth in the development effort to stay on track for assembly in orbit in March 1995.

In addition, the portion of the Research and Program Management (R&PM) budget managed by the Office of Space Flight totals $952.6 million and supports 10,361 full time equivalent positions. With Appropriation Realignment, the R&PM budget has taken on an even greater role as an integral part of the OSF program. The net result of Appropriation Realignment on Institutional requirements is that manpower, facilities, and services are more directly driven by program requirements. As program requirements increase, the demands on the institutional activities supported by R&PM also increase. This area of the budget also supports our travel requirements, which are considerable due to the wide geographic dispersion of our programs including the Space Station's international partnership. As Space Station's scope and pace increase, we require increases in both R&PM funding and the program's manpower ceiling. As efforts of Station contractors expand, our direction and oversight must also grow to ensure that R&D funds are spent wisely and efficiently. These activities are the basis upon which we are able to effectively conduct the critical Office of Space Flight Programs.

The NASA budget also includes several projects in the Construction of Facilities (CoF) request which are critical to the Space Station program. In 1991 we will begin construction of the Space Station Processing Facility at Kennedy Space Center (KSC), Florida, and the Neutral Bouyancy Laboratory at Johnson Space Center (JSC), Texas. We will also continue construction of the Space Station Control Center, and complete construction of the Space Station Training Facility at JSC. Full funding for these facilities is imperative to support plans to begin Space Station launch and assembly operations in early 1995.

Shuttle Production and Operational Capability

The $1,302.0 million in Shuttle Production and Operational Capability is an investment in capabilities to effectively operate the fleet of Shuttle orbiters, and also provides for continued modification and improvement to the flight elements and ground facilities necessary to expand capabilities and safety margins. The total is distributed as follows: $213.6 million for orbiter operational capability, $822.9 million for propulsion systems, and $265.5 million for launch and mission support.

Orbiter Operational Capability

This $213.6 million funds capability investments in orbiter systems to support the mission model and operational requirements. Included are provisions for the logistics capability, inventory of spares, previously approved systems improvements, safety modifications, and engineering analyses and integration capabilities. The amount also provides for orbiter support activities such as the remote manipulator system, verification and validation of avionics interfaces, and the Convair 990 program for landing system analysis. Systems integration receives $11.1 million of the amount, while $52.4 million is earmarked for structural spares and $21.7 million for orbiter spares. Finally, $15 million is included for work on the Extended Duration Orbiter (EDO), in addition to the cryogenic kit being planned for development under a commercial arrangement with Rockwell International. The remaining $113.4 million is for orbiter modifications, improvements, and previously-mentioned support.

Propulsion Systems

The Space Shuttle Main Engine (SSME) program receives $430.9 million for the continued production of additional flight hardware and spare parts investments as well as continuation of development programs, including improvements to the current configuration and the alternate turbopump. Alternate turbopumps are being developed due to the limited operational life capability of the current high pressure turbopumps, which require overhaul after one or two flights. The new pumps will incorporate improved safety margins, life spans and reliability with a design requirement of 55 flights between overhauls. The product improvement program strives to improve safety and reduce costs, and has already done so in current production. It is anticipated that SSME modifications will likely increase its weight, but the resulting loss in performance will be overcome with inception of the Advanced Solid Rocket Motor (ASRM).

The Solid Rocket Booster (SRB) program receives $82.9 million. Primary focus of this funding is on continued evaluation and analysis of flight data to thoroughly assess the redesign. Modification of booster hardware will continue with the objective of obtaining the capability of at least 20 flight usage.

The Advanced Solid Rocket Motor (ASRM) program receives $309.1 million in fiscal year 1991, excluding facility construction costs. The amount supports the first full year of development as well as the continued buildup of plant equipment for the planned production facilities. The ASRM facility and equipment requirements are funded through direct appropriation rather than the private financing proposed in the FY 1990 budget. The Request for Proposal (RFP) for the development phase of the ASRM was issued in August 1988. One contractor was selected for development with contract start anticipated during the second quarter of FY 1990. The development program is anticipated to extend for five years with the first flight of ASRM hardware in FY 1996. The scope of the development will include modification or acquisition of facilities, development and test of the new design, and production of verification units. The ASRM will increase reliability and safety in both the Solid Rocket Boosters and the total Shuttle system. It will also provide a projected 12,000 pounds of increased performance. Its development is comparable in scope and complexity to that of the SRM, while the technological base is greater than that at the start of the SRM project.

Launch and Mission Support

This activity directs $114.9 million to launch site equipment, to include activities improving the capability and processing efficiency in support of the flight rate. Included are the shuttle processing data management system, the OMRF upgrade, launch processing system equipment replacements, and the launch team training system.

The mission operations and support capability receives $150.6 million, providing for completing the replacement of host computers, automatic data processors, and other equipment in the mission control center. The Flight Analysis and Design System (FADS) system, dual-capability flight control room, improvements to weather prediction, information handling, mission control systems, and contingency landing sites are also covered in this account. Funding is also earmarked for mission support such as crew equipment — principally Extravehicular Mobility Units (EMU). Operations effectiveness and other support functions continue to support program-wide requirements, including flight safety, mission success, and flight rate capability.

Space Transportation Operations

This account provides launch services to NASA payloads using a mixed fleet approach of both the Shuttle and ELVs. Launch services are also provided on a reimbursable basis to the Department of Defense, other civil agencies, and certain commercial and international users. The Shuttle Program launch schedule is based on eight flights in FY 1990, ten in FY 1991, and eleven in FY 1992. The ELV launch schedule is a mix of launch systems in four performance classes: small, medium, intermediate, and large.

Flight Operations

The $815.6 million in this account is distributed to Shuttle mission support, integration and support functions. Mission support includes the flight operations activity at JSC for the ten missions to be flown in FY 1991 and initial efforts for FYs 1992 and 1993. These include maintenance and operation of all ground facilities necessary for flight preparation and execution, and instruction of flight and ground controllers. Also included are flight design activities and analyses and conduct of planning necessary for each mission and maintenance of flight software. This budget will incur some support costs previously funded separately by the DOD, which plans to incrementally remove its requirements for secure operations support. Also included is sustaining engineering required to integrate all flight and ground elements and to assure systems safety and integrity, payload compatibility and interfaces, and crew operations and training. Support also continues for procedure and hardware modifications resulting from failure and criticality reviews, and sustaining engineering activities that ensure maintainability, reliability and anomaly resolution during operations. The amount also covers aircraft for proficiency, training and orbiter ferry requirements.

Flight Hardware

The $1,467.2 million in this category provides for procurement of External Tanks (ET), manufacture and refurbishment of Solid Rocket Booster (SRB) hardware and motors, and operational support to the orbiter including spares, ET disconnects, spare components and flight support for the main engines, and maintenance and refurbishment of flight crew equipment. Also, manufacture of flight support motors for static firing will continue in FY 1991, in order to monitor consistency of production characteristics, quality process, and design changes. Moreover, testing will be required to flight certify new sources of ammonium perchlorate for SRB propellant, and carbonized rayon used for nozzle parts.

Launch and Landing Operations

Manpower and support services necessary for processing launches from KSC are covered by the $606.6 million in this account. Funding also supports the manpower required for sustaining engineering, provisioning, logistics, launch processing system operation and maintenance, and maintenance and modification of all other Shuttle-related ground support equipment and facilities. Also included are funds for maintaining the Dryden Flight Research Facility, California, as a landing site.

Expendable Launch Vehicle (ELV) Services

The ELV budget request for FY 1991 of $ 229.2 million will continue to fund procurement of launch services from the private sector for civil government missions. Specifically, activity will continue on the Geotail (with Japan), Wind, and Polar missions under the competitively selected Medium ELV (MELV) launch services contract awarded in fiscal year 1990, as well as initiation of support for the U.S.-Canadian Radarsat mission. Under the MELV contract NASA will obtain three firm and twelve optional Delta II launch services to support NASA scientific requirements through the 1990's. The U.S.-German Roentgen Satellite (ROSAT) mission will be launched in 1990 on a USAF purchased Delta, while fiscal year 1991 funds will support launch of the Extreme Ultraviolet Explorer (EUVE) on a USAF procured Delta in 1991.

In 1990 NASA will issue a Request for Proposals (RFP) to competitively procure Small-class ELV (SELV) launch services from the private sector to support the NASA Small Explorer Satellite Program. The FY 1991 budget request provides initial funding for a series of seven firm and three optional SELV launch services, as well as funding to continue support to the remaining three Scout vehicles planned for launch through 1993.

Unlike the SELV and MELV Programs which lend themselves to procurement of a series of firm and optional launch services, NASA's intermediate class launch requirements (payloads up to 30,000 lbs,) are being procured competitively on an individual basis. In November 1989 NASA signed a launch service contract to support the Mars Observer mission on a commercial Titan III vehicle which is supported by the fiscal year 1991 budget request. Intermediate class launch services for the Solar Heliospheric Observatory (SOHO) for the European Space Agency, and the Mobile Satellite (MSAT) will be initiated in FY 1990. The Combined Release and Radiation Effects Satellite (CRRES) launch on the first commercially produced General Dynamics Atlas I vehicle in 1990 will usher NASA into the new era of launch services.

NASA will continue to rely on the USAF for support to Large ELV-class requirements (payloads of 40,000 lbs.), since Titan IV's are currently unavailable commercially. The FY 1991 budget request continues mission integration activities to support both the CRAF and Cassini missions scheduled for launch on Titan IV's.

Space Transportation Capability Development

The $773.4 million in the Space Transportation Capability Development account is shared by a number of programs which cut across the OSF organization, and is distributed among eight NASA installations and Headquarters.

Spacelab

The Spacelab funding request for FY 1991 is $130.7 million. This funding level will support six Shuttle missions using Spacelab hardware in FY 1991. It will also support preparations for eight missions planned to be launched in FY 1992; and to initiate flight hardware processing for eight additional missions scheduled for FY 1993. In conjunction with supporting a substantial part of the Shuttle flight manifest during these years, the Spacelab funding will provide the necessary engineering and development activities for hardware recertification and return to flight status.

The Spacelab will return to flight in FY 1990 with the launch of two major scientific missions: Astro-1, an igloo pallet with an Instrument Pointing System (IPS) scheduled to be launched in the third quarter and a Space Life Sciences-1 (SLS) module mission scheduled for the fourth quarter. In FY 1990 we will be very active preparing and processing flight hardware for three international Spacelab module missions planned to be flown in FY 1991: the International Microgravity Laboratory (IML) mission, the Japanese/American (SL-J) mission, and the Italian/American cooperative Tethered Satellite System (TSS) mission. Spacelab hardware processing will also be in progress to support DoD payloads. One major DOD mission is the SDI Starlab module mission scheduled for launch in early FY 1992. Furthermore, Spacelab hardware preparation and processing in FY 1991 will be initiated to support major Shuttle missions in FY 1992 such as micro gravity materials processing type missions: United States Microgravity Laboratory-1 (USML) and United States Microgravity Payload-1 (USMP), Shuttle Radar Laboratory-1 (SRL), Atlas 2, SLS-2, and the German Spacelab module mission SL-D2.

In addition to these missions, the Spacelab FY 1991 funding requirements will support the complete development of the modified Hitchhiker MPESS structure for experiments starting in 1992. The processing of many Hitchhiker and Get-Away-Specials (GAS) will occur during this timeframe. In December 1990 and June 1991, crossbay GAS bridge carriers will be launched with up to twelve GAS customer payloads per mission.

Spacelab hardware is used to support as many as eight missions a year with projections to continue this level of effort through the late 1990's. During this timeframe additional planned uses for Spacelab carrier systems to support Space Station Freedom as a precursor and test beds will be considered. Funds for the planning of the refurbishment and replacement of Spacelab carrier hardware is included in the FY 1991 request to meet the launch demands. We are currently conducting a Spacelab improvement study with the users which will be completed this year. The results of this study will be implemented in FYs 1991 and 1992.

Upper Stages

The Upper Stages budget request for FY 1991 is $91.3 million. The Upper Stages program encompasses procurements of Inertial Upper Stages (IUS), Transfer Orbit Stage (TOS), Centaurs, and a Solid Propulsion Integrity Program (SPIP). Upper stages boost payloads to orbits and trajectories not attainable by the Shuttle or ELVs alone. Requested funds will procure stages and provide technical monitoring and project management. IUS vehicles are procured through the DOD, and TOS vehicles are procured directly by MSFC. The TOS upper stage is being commercially developed and will be procured directly from the vendor. The Centaur is an integral element of the Titan IV/Centaur vehicle procured by the DOD and launched for NASA. MSFC manages the Solid Propulsion Integrity Program (SPIP), initiated in 1984, which establishes an engineering base for improving the success rate of U.S.-built solid stages, and is closely coordinated with the DOD to avoid duplication of efforts in this vital program.

In FY 1990, IUS production continues for the Tracking and Data Relay Satellites (TDRS) E and F, and the Ulysses mission. The Ulysses mission will use an IUS upper stage with a modified Payload Assist Module (PAM-S), a commercial upper stage. NASA launched one IUS mission (Galileo) in FY 1990 aboard the Space Shuttle. The TOS upper stages for the Advanced Communications Technology Satellite (ACTS) mission and the Mars Observer (MO) mission will continue production in FY 1990. The SPIP program will continue work on building the engineering base on solid propulsion stages in the areas of nozzles and bondlines, propellants, internal flows, and verification testing.

The FY 1991 funding request will support the IUS/Ulysses and IUS/TDRS-E launches, preparation of the IUS/TDRS-F for a FY 1993 launch, and initiation of production of an IUS vehicle for a TDRS-G launch in FY 1995. The TOS for the MO and ACTS missions will continue production for launch in FY 1992. Two Centaur vehicles will be procured for the CRAF and Cassini planetary missions to be launched in FYs 1995 and 1996, respectively. The production of the two Centaurs will be initiated by DOD as part of the Titan IV/Centaur program. The SPIP will continue its investigation of materials, design tools, fabrication processes, and controls, will examine product evaluation and verification methods, and will improve engineering practices, procedures, and communications within the solid propellant community.

Engineering and Technical Base

The largest account under Capability Development is Engineering and Technical Base (ETB) which receives $218.5 million of the total. The ETB core varies from center to center due to programmatic and institutional differences. To supplement my earlier remarks about the accomplishments and plans for ETB, I would like to add comments about elements at the OSF centers. At Johnson Space Center (JSC), Texas, and White Sands Test Facility, New Mexico, ETB provides for five-day, one-shift operations in engineering and development laboratories. ETB provides center-wide computational services and Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) support for JSC and Marshall Space Flight Center (MSFC), Alabama. At Kennedy Space Center (KSC), Florida, the core level provides for technical laboratory support in such areas as robotic applications for launch vehicle umbilical and inspection systems, development of polymer coatings for launch structures, prototyping and testing equipment in support of ASRM and Shuttle-C, research in artificial intelligence applications, new fiber optics and digital electronics test and evaluation, and SRM&QA functions in direct support of the launch process. At MSFC, the core level provides for multiprogram support to technical laboratories and facilities, and to test facility operations. Starting in FY 1990, the ETB engineering support at MSFC will play an important role in ASRM development. At Stennis Space Center (SCC), Mississippi, ETB funding is utilized to maintain the supporting infrastructure necessary for current and future propulsion test programs, including SSME testing, ALS component testing, and ASRM testing. This infrastructure includes equipment, support personnel, and related special studies.

For FY 1991 the ETB budget provides capability to accomplish the following activities:

* Critical specific science and engineering support required for systems analysis and integration, propulsion, avionics, materials and processes, structures, and dynamics capabilities which are either not readily available or cannot be obtained within the civil service work force, especially at JSC and MSFC as the Space Station development continues and intensifies, and ASRM activity increases. In addition, the increasing flight rate places added demands on launch support.

* Enhanced support required for new programs and expanded technology associated with robotics laboratories, improved optical processor technologies, microwave integrated circuitry, artificial intelligence applications, and for new Space Station Freedom program needs and design concepts.

* Increased SRM&QA needs at all OSF centers.

- Replacement of a significant backlog of aging and obsolete laboratory equipment which continues to deteriorate as equipment requirements are deferred due to limited funding.

Payload Operations and Support Equipment

Payload Operations funding in the amount of $94.2 million is required for continued payload services to currently scheduled launches. Major NASA payloads to receive support include Hubble Space Telescope (HST), Tracking and Data Relay Satellite (TDRS), Space Radar Laboratory (SRL), Space Life Science Laboratory (SLS), Upper Atmospheric Research Satellite (UARS), and Gamma Ray Observatory (GRO). Funding is also required to initiate technical integration and operations activity to assure compatibility between Shuttle capabilities and Space Station transportation requirements. A docking system is being developed as part of this activity.

Payload Support Equipment funds of $28.3 million reflect the requirement to modify and upgrade selected payload integration facilities for safer and more efficient operations. Also included are orbiter/payload interface hardware for groups of payloads, cargo bay cabling, modified aft flight deck panels, and associated displays and controls.

Advanced Programs

The Advanced Program Development request is $53.2 million in FY 1991. Identification of future space transportation and related initiatives is the focus of this program area which provides the technical as well as the programmatic data for future national decisions on space transportation alternatives. Definition study and supporting advanced development activities will continue in FY 1991 with primary emphasis on advanced space transportation systems, advanced operations support systems, and satellite servicing systems. Other activities include tether applications and orbital debris studies.

Concept definition (Phase A-prime) studies of the Assured Crew Return Vehicle (ACRV) will be conducted in FY 1990 with the follow-on systems definitions (Phase B) planned in FY 1991. The FY 1991 effort will include preliminary design of space-based vehicle concepts for three mission areas: crew illness or injury, Space Station Freedom accidents, and Space Shuttle unavailability.

The Shuttle-C definition effort is focused on a near-term heavy lift capability utilizing Shuttle elements while replacing the Orbiter with a cargo carrier. The preliminary design for the basic Shuttle-C concept will be completed during FY 1990. Heavy lift vehicle studies will be initiated in FY 1991 to build upon the Shuttle-C studies.

Concepts for a high performance upper stage, the Space Transfer Vehicle (STV), will continue to be studied during FY 1990. Originally conceived as a near-term solution for unmanned planetary and geosynchronous mission requirements, the studies have also considered evolutionary concepts to meet space transfer needs for human exploration.

Improved cost effectiveness, mission success, and flight safety are the objectives of operations support systems studies and development. Two current projects are being transitioned into flight operations process for FY 1990. One of these enables the efficient use of distributed data processing systems for mission support and the other utilizes expert system technology to automate the task of error message reporting.

We have been involved with the DOD and the Department of Transportation on a research plan focused on assessing the orbital debris environment, developing design criteria for the Space Station Freedom, minimizing debris, determining spacecraft survivability, and using results of this research to formulate future regulatory options. During FYs 1990 and 1991, studies will continue to assess the orbital debris environment and to develop techniques to protect in-space assets.

NASA completed a pre-Phase B study of the Satellite Servicer System (SSS) Flight Demonstration. This study co-funded by DOD/SDI was focused on using the OMV and elements of the Flight Telerobotic Servicer (FTS) to demonstrate autonomous rendezvous and docking, and supervised autonomous orbital replacement unit exchange as well as fluid resupply. Future development on an operational SSS will enable NASA or DOD to service satellites in orbits not reachable by the Shuttle as well as safely undertake hazardous servicing missions. Utilizing the OMV and elements of the FTS will enable both NASA and DOD to develop a cost effective servicing infrastructure. A jointly funded and jointly managed Phase B effort will be initiated in fiscal year 1990.

This year we also completed the engineering design and fabrication of three flight experiments related to satellite servicing. The Optical Communications through the Window (OCTW) experiment will provide payload bay users with a stand-alone communications link between the Shuttle payload bay and the crew cabin. The Voice Controlled TV (VCTV) will improve STS crew performance by providing voice control for the Shuttle bay TV cameras. Both of these flight experiments are manifested to fly in October 1990. The Small Expendable Deployer System (SEDS) will demonstrate the ability to routinely de-orbit material from a space station or place instruments deep into the upper atmosphere using an inexpensive expendable tether system. The SEDS concept will be demonstrated as a secondary payload on an Air Force Delta II rocket in mid 1991.

Advanced Transportation Technology

Our objective for advanced transportation technology is to define concepts and demonstrate initial launch vehicle technologies which will support the heavy lift launch vehicle requirements of the Human Exploration Initiative. Systems analysis and concept definition of wide-body and cryo tanker heavy lift launch vehicles will be conducted in conjunction with Shuttle-C, the Advanced Launch System (ALS), and other potential vehicle concepts.

NASA is requesting $40 million to augment the ALS Space Transportation Main Engine (STME) systems definition and advanced development efforts in FY 1991. The ALS program has been restructured to accommodate a reduction in DOD FY 1990 funding. This restructuring includes a significant reduction in scope for the DOD-managed vehicle studies and a re-focusing of priorities toward propulsion technology. NASA will continue the management responsibility for the Advanced Development Program (ADP) and liquid engine systems definition and advanced development work, and will assure that critical tasks are completed to support future decisions on an STME program. The augmentation is necessary to assure technology maturation to support the development of the next generation, highly reliable yet low cost engine which could have application for the Human Exploration Initiative. The Component Test Facility at Stennis Space Center is under construction and supports the engine development schedule.

We are also requesting $10 million in FY 1991 to perform design studies which will address the specific requirements for a tanker to move large quantities of cryogenic propellants to orbit, and for a large volume cargo carrier. These studies will consider both Shuttle derivatives and the ALS vehicle concepts.

Also in FY 1991, $3.9 million has been requested to address unique civil requirements not covered in the ALS baseline program. The ALS civil studies include definitin of civil mission requirements, transportation infrastructure analysis (ETO vehicle and space transfer vehicle trades), space transfer vehicle concepts, and Space Shuttle/ALS booster commonality analysis.

Tethered Satellite System (TSS)

The first TSS mission is scheduled in September 1991. The final integration and launch preparation for this mission, as well as post flight data reduction, hardware disassembly and system update will require a funding level of $17.9 million in FY 1991. During the FY 1990 activities, the TSS will undergo final assembly, system level qualification testing and the initiation of the hardware integration process at KSC. Delivery of flight hardware to KSC is scheduled for early summer 1990.

The TSS is a cooperative US/Italian development of a reuseable Shuttle based space facility. The first mission will demonstrate the capabilities of the system and conduct electrodynamic investigations. The TSS will be deployed 20km (12 miles) above the Orbiter on a conductive tether. Electricity will be generated as the connected Orbiter and Satellite pass through the magnetic field lines of the earth. Both the satellite and the deployer, which is attached to the Orbiter bay, will be instrumented to study the generation process. Italy will develop the satellite and provide integration of all scientific instruments. NASA will provide the TSS deployer, perform system-level engineering and integration, and deploy the spacecraft from the Shuttle. An Italian payload specialist will fly on the first TSS mission.

The TSS concept can be used to study near earth atmosphere in regions unreachable by conventional satellites, to provide applications of practical, as well as, scientific value to the Space Station, and as a tool in planetary exploration. We are currently investigating the potential of a second mission to conduct aerothermodynamic investigations in the 130km orbital region.

Orbital Maneuvering Vehicle (OMV)

The OMV request for FY 1991 is $85.4 million which is substantially less than the FY

1991 estimate submitted in FY 1990 Budget ($175.4 million). This reduction is a result of restructure of the OMV program and rescope of the design which were undertaken because of cost-growth threats, and reassessment of vehicle requirements.

The restructured OMV design will be capable of performing orbital operations up to 275 nautical miles beyond the practical operational range of the Shuttle. Using remote man-in-the-loop control for proximity operations, the OMV will deliver, retrieve, and reboost a broad spectrum of satellites. Specifically, the OMV will reboost the Hubble Space Telescope (HST) up to approximately 180 nautical miles above the Shuttle orbit and the Advanced X-Ray Astronomical Facility (AXAF) 140 nautical miles above the Shuttle orbit. In addition, it will reboost a variety of satellites to their original operating orbits, retrieve them for repair at the Shuttle, and return them to their operating orbits. In addition, the restructured design will accommodate system enhancements in propulsion, power generation, navigation, and payload support services which would be added as mission kits as future requirements are defined.

The FY 1991 funds will finalize the OMV design and initiate fabrication and testing. The OMV development schedule is paced to support a demonstration flight in April 1995. The program Critical Design Review is scheduled for April 1991.

Space Station

In presenting the FY 1991 Space Station Freedom budget request, there are four principal points about the program which I wish to emphasize:

First, our objectives for Space Station Freedom have not changed. For our science program, Freedom offers a laboratory for research in many scientific disciplines and a platform for instruments to look out at the universe as well as back toward the Earth. For technology development, Freedom will be a unique national facility - a testbed for evaluating technologies, procedures, and design approaches for potential application in future space systems. For our exploration program, Freedom's manned base represents the establishment of a permanently manned oupost in space and a stepping stone for the missions of the future.

Second, our progress to date on the Space Station has been substantial. The First Element Launch milestone is one year closer now than it was at our last budget hearing before this Subcommittee, and our design and development effort is moving forward accordingly on all fronts. The Space Station is developing hardware and necessary infrastructure. Many of our important accomplishments to date involve tangible hardware items, including hundreds of breadboards, proof-of-concept development items, testbeds, test articles, mock-ups for human factor analysis, and technology demonstration hardware.

Third, some program adjustments have been required in the last year, but the basic integrity of the Space Station program is intact. The reduced funding for FY 1990 and the resulting need to minimize near-term program costs, technical risks, and schedule risks forced some changes in program plans, primarily involving the schedule for outyear assembly milestones and addition of planned capabilities.

Despite these recent adjustments, however, the fundamental objectives of the Space Station program are unchanged, and the planned capabilities of the Space Station are maintained.

Finally, as you well know, full funding for FY 1991-1993 is necessary if we are to avoid additional disruptions in the Space Station development effort. The stability that is required can only be provided by multiyear funding. This Committee has understood this reality and demonstrated its strong support for the program by approving the Space Station's existing multiyear authorization. Renewal of this multiyear authorization and initiation of a multiyear appropriation are essential if we are to complete the baseline Space Station before the start of the twenty-first century.

There are two significant differences between the FY 1991 budget request and previous requests. First, beginning with FY 1991 the Space Station budget no longer contains funding for the Polar Platform project, which has been transferred to the Office of Space Science and Applications as part of the Earth Observing System (EOS) program. Second, for the first time the request contains funding for Human Exploration Initiative study activities in the Advanced Programs budget line. These activities will examine Space Station capabilities and technologies that may be required to support manned missions to the Moon and Mars.

Work Package 1

In FY 1991, the Work Package 1 team will be heavily involved in the final design of its distributed systems in preparation for their CDR in early FY 1992. The preliminary design of the U.S. laboratory module will be completed, its PDR will be conducted, and final design activities will begin in preparation for a CDR in FY 1992. Engineering manpower for design and analysis activities will increase to support the FY 1992 PDRs for the habitation module and logistics carriers. Other key activities include procurement of hardware for development and qualification testing of the Environmental Control and Life Support System (ECLSS), and testing of the integrated ECLSS subsystems in a simulated module. Structural test articles for the nodes and cupolas will be fabricated and used to conduct structural loads and environmental tests.

Supporting development activities at Marshall Space Flight Center include providing test facilities and related support (such as meteoroid/debris protection testing, seal development, berthing mechanism testing, module pressure/structural testing, and environmental testing) for prime contractor development efforts. Also included are ECLSS systems analyses, development testing and simulations, and materials properties assessments, including metallurgical support and lubricant evaluation. Other planned supporting development activities include systems engineering and integration, as well as implementation of a comprehensive technical and management information system.

Work Package 2

The Work Package 2 team will focus on the CDR for the Data Management System in support of the first delivery of a data management system kit in FY 1991.

Engineering development units for the assembly work platform, the mobile transporter, the astronaut positioning system, the communications and tracking system, the hyberbaric hatch, and the thermal control system will be delivered. Testing will be conducted to support the program CDR the following year. Engineering design and evaluation of the guidance, navigation, and control system, mechanical systems, and other systems will continue.

Supporting development activities will continue in preparation for the CDR. At Johnson Space Center, supporting development provides for all the test and facility manpower required for independent analytical support to assess system design viability, test article outfitting, and testbed operation. For example, supporting development activities for the truss assembly will include integrated loads and dynamics analysis, structural testing, materials usage assessment, structural assembly and berthing verification, and hypervelocity impact testing. The manpower, laboratories, computational capabilities, and hardware required for these analytical tasks will be supplied by supporting development contractors.

Work Package 3

After the Polar Platform is transferred out of the Space Station program, the primary item remaining in this work package is the Attached Payloads Accommodation Equipment (APAE). The preliminary design of the APAE will be completed, the PDR will be conducted, and detailed engineering design and analytic work will begin. Goddard Space Flight Center's supporting development activities include defining APAE common equipment, providing data support services and technical discipline support to structural/thermal analysis, defining contamination and monitoring requirements, and performing risk assessments.

Flight Telerobotic Servicer (FTS)

The major FTS activity next year will be integration and launch of the first development test flight on the Shuttle. The primary objective of this test flight will be to evaluate the FTS design and man-machine interfaces through the use of a manipulator system, a preliminary workstation, and software. DTF-1 hardware and software testing will receive particular emphasis, and astronaut training on the DTF-1 training system and simulator will begin after completion of checkout. PDR's for the second development test flight and the FTS itself will also take place, and FTS components will undergo continued development and test.

Supporting development activities include development of equipment for crew training, flight operations support, and integrated flight simulations. Efforts will continue on applications procedure development and studies supporting potential enhancements.

Work Package 4

The Work Package 4 team will continue work on the development and qualification of the solar cells and blankets. Energy storage assembly qualification cells will be fabricated and tested. Detailed design and testing of module items such as electrical equipment assemblies and beta gimbals will continue. Power management and distribution (PMAD) system components and orbital replacement units will undergo detailed design during FY 1991. End-to-end testing of PMAD components will be completed in late FY 1991, and hardware will be delivered to Lewis Research Center in preparation for the electrical system integrated test planned the following year.

Supporting development activities include independent verification of the prime contractor systems engineering and integration efforts. Also included is the provision of a facility to conduct electrical integrated testing, "fleet leader" battery testing, and system validation of the photovoltaics module.

Operations/Utilization Capability Development

JSC will complete requirements definition and design of the Space Station Training Facility and the Space Station Control Center. Construction of these facilities will begin, with the objective of having them ready in 1993. Related hardware and software acquisition activities will also begin. Software development activities of the operations planning and analysis system will continue at an increased pace.

MSFC will define design and operations requirements for the Payload Operations Integration Center to provide an initial operational capability in 1995. A request for proposals will be released for systems development and procurement of the Payload Training Center, which is scheduled to have an initial operational capability in 1995.

KSC will begin significant equipment purchases, and will increase activity in planning, scheduling, systems software development, and manpower buildup for the Test, Control, and Monitor System (TCMS) and the Space Station Processing Facility. The TCMS PDR and the logistics information system CDR will be completed. Requirements for the Space Station Hazardous Processing Facility will be baselined.

Level II will refine facility requirements for Space Station operations and utilization in the Functional Control Documents, which will provide a basis for coordinating operations and utilization planning activities of the NASA centers and international partners.

Management and Integration

Management and integration activities will continue to focus on engineering integration, expansion of the Software Support Environment (SSE), and operation of the Technical and Management Information System (TMIS). The Space Station Engineering and Integration Contractor (SSEIC) will assist NASA in a broad range of activities required to prepare for completion of the program PDR in December 1990 and the CDR in FY 1992. These system engineering tasks include top-level stage definition for key stages of assembly, analysis of stage performance and assessments of the design against the requirements. The system integration tasks include integrated scheduling and development of verification plans, engineering data bases, and interface control documentation. Program plans will be developed for system safety and quality assurance, launch package integration, on-orbit assembly and checkout, and integration with the Space Shuttle. The SSEIC will have an increased role at the field centers based on the relocation of the systems and element integration responsibilities to JSC and MSFC. For example, the SSEIC will support the Level II offices at these centers in preparing and maintaining Interface Control Documents, Architecture Control Documents, and Baseline Configuration Documents.

The SSE operational capabilities will be expanded by increasing and improving existing capabilities in the Software Support Environment Development Facility and the Software Development Facilities at contractor sites. In FY 1991, the Software Production Facilities at the field sites will be supported and additional facilities put in place as required. Incremental delivery of TMIS products will continue. Efforts will continue toward completing electronic bridges needed to link together contractors, NASA centers, and domestic and international users. Technical and resource information management, tracking systems, and databases will continue to be developed, with emphasis on those elements required to support the program PDR and CDR.

Advanced Programs

In FY 1991, Advanced Development and Advanced System Studies activities will ensure that the baseline Space Station will have the capability to add new functions, expand planned resources, and avoid obsolescence through technology upgrades. Advanced Development tasks will continue to emphasize advanced automation, robotics applications, and technology development to improve flight and ground system productivity and reduce long-term operations costs. Activities planned include: demonstration of knowledge-based automated subsystem control for flight and ground systems applications and cost effective software test/integration; and, demonstration of FTS operator/robot shared control in support of both the DTF-1 flight experiment, and the demonstration of large robot control from a remote site. Advanced System Studies will continue definition of an evolution reference configuration, including analyses to identify baseline configuration impacts and operational compatibilities associated with the more capable Station. Continued analyses are planned of the Station's distributed systems to define and document critical evolution design requirements before hardware construction.

The Human Exploration Initiative will likely evolve Space Station Freedom beyond its baseline configuration capabilities. Supporting potential transportation requirements may necessitate additional structure, power, servicing, and other capabilities. $20 million of the Advanced Programs request is for exploration technology to begin to study systems-level enhancements, and to begin the advanced development and preliminary design of the following crucial systems: Space Station-based EVA and high pressure suits; solar dynamic power; expanded hybrid power distribution and management system; and advanced propulsion. A special study on concepts of advanced automation and robotics for potential space transfer vehicle assembly, checkout, and servicing will be initiated to determine an appropriate mix of automation and EVA that may be needed to support potential mission operations. The focus of these efforts will be to ensure that the essential hooks and scars to support HEI are identified and incorporated into the baseline program. Planning for these activities is being closely coordinated with the Exploration Technology program.

Space Station Operations

FY 1991 is the first year for funding operations. The early operations activity includes the establishment of a logistics system and spare parts for the flight systems. The FY 1991 funding in this area will allow for the procurement of long-lead materials required to begin establishing the spares inventory. These procurements need to be initiated in FY 1991 to ensure that spares are available to support launch site processing as well as on-orbit operations for early assembly flights. As the Space Station Program moves into its operational phase, the operations budget will provide for sustaining engineering, logistics, crew training, hardware processing, and other operational costs.

PROGRAM CONCERNS

Space Transportation

Our space transportation program has several major near-term concerns to which I wish to direct the Committee's attention. First among these is hardware obsolescence. The first Space Shuttle was delivered over ten years ago and was the product of 1970s design and construction. Our planning calls for operation of these orbiters for at least another twenty years, and perhaps more. In order to assure the Shuttle remains safe, serviceable, and effective in meeting evolving transportation requirements, it is imperative that we plan for the replacement of systems with current designs and technology. This has been an ongoing process with the development of such items as improved General Purpose Computers, solid state star trackers, and enhanced multiplexer-demultiplexers. Eventually, other Shuttle systems must be upgraded to modern flight standards. Examples are glass cockpit displays and the Global Positioning System Navigation System. Such improvements require years of advance development.

I also wish to reiterate our needs in the Research and Program Management account. Appropriation realignment made the R&PM budget significant to the programs in ways which are simple, but vital. For example, printing flight documentation is funded in R&PM, although it is a pre-flight requirement. Utility bills are paid in R&PM, yet without electricity, heat, and air conditioning, we cannot function. Finally, all civil servants are paid in R&PM funds, as is the cost of the travel they perform in support of our programs. Our FY 1991 request is austere, but supports these programs.

Other program challenges and concerns of which the committee should be aware are as follows:

- Meeting the increasing flight rate while maintaining high safety levels during orbiter processing.
- Major fleet modifications and implementations, such as drag chute installation and redundant nose wheel steering, will require orbiter down time and challenge our ability to meet the planning manifest.

- Maintaining our capability to build additional orbiters. Final delivery of components to Endeavour (OV-105) will mean vendors will have smaller business bases and either charge greater costs or layoff technical personnel. Loss of this capability is a concern to our logistics program and affects future decisions on orbiter production.
- As experienced engineers transfer and retire, significant corporate knowledge is lost. Attracting and retaining good people is a high priority.
- Due to age, service life uncertainties, and structural concerns, we must begin planning for procurement of replacement Shuttle Training Aircraft (STA). The current fleet leader has a predicted end-of-service life of 1994.

Space Station Freedom

The following are our primary challenges and concerns regarding the Space Station Freedom program:

- Implementing our plan to begin assembly in early 1955 and complete the Space Station by mid-1999 depends on maintaining an adequate and stable funding profile. At the very least, inadequate funding would disrupt the development effort, delay our schedule, and increase program costs.
- The program will conduct more than 80 subsystem PDRs in 1990 leading up to system-level PDR in December 1990. The intensity and manpower requirements across the program will be focused on this accomplishment.
- The program will define and baseline element-to-element interfaces and element-to-distributed system interfaces. Baseline Configuration Documents will define hardware locations within modules and on the truss structure. Functional Control Documents will define the flight-to-ground system architecture. Architecture Control Documents that were baselined last fall will continue to be updated as necessary to reflect approved changes in the upcoming PDRs.
- Weight and power controls were baselined at the work package level last fall. Continued assessment of these controls and baseline control of crew time and volume will occur this year.
- Debris protection criteria will be baselined and reflected in the PDR this year. In addition, a debris protection plan will be developed that minimizes the likelihood of impact damage.
- We will continue to assess operations costs to refine our earlier estimates. Life cycle cost control depends on understanding and controlling operations costs.

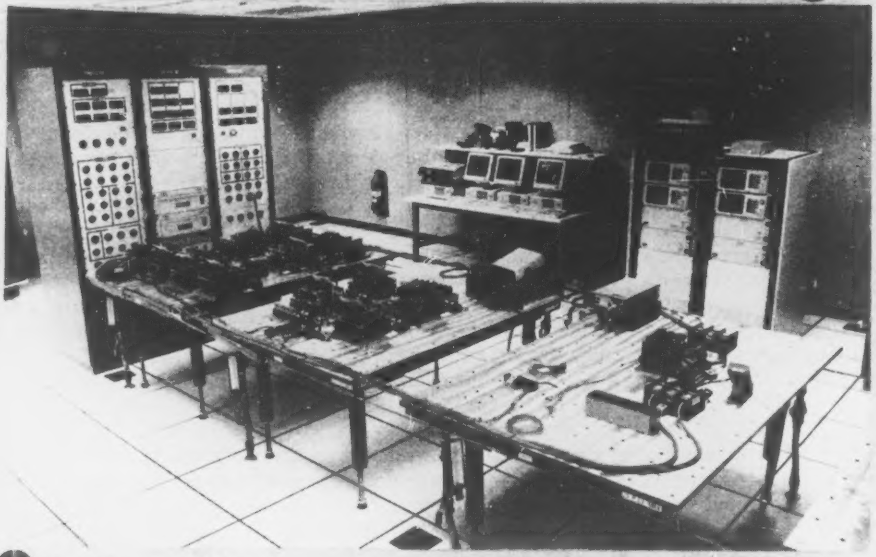
CONCLUSION

We often draw analogous comparisons between the space program and previous breakthroughs in transportation which have opened new vistas, economic opportunity, and cultural growth. Space transportation has occupied only a brief moment in human history, and has quickly transformed our lives in ways we could never have anticipated. As our capabilities mature and our opportunities expand, even the most optimistic visionaries likely can not forecast the achievements and wonders which lie ahead. As the next step toward this bright future, we are eager to work with you, Mr. Chairman, and the Members of the Committee, toward the expedient implementation of this budget

I will be pleased to respond to any questions you may have concerning this budget and these important issues.

Rocketdyne Electric Power Test Bed

FREEDOM



Rockwell International
Rocketdyne Division

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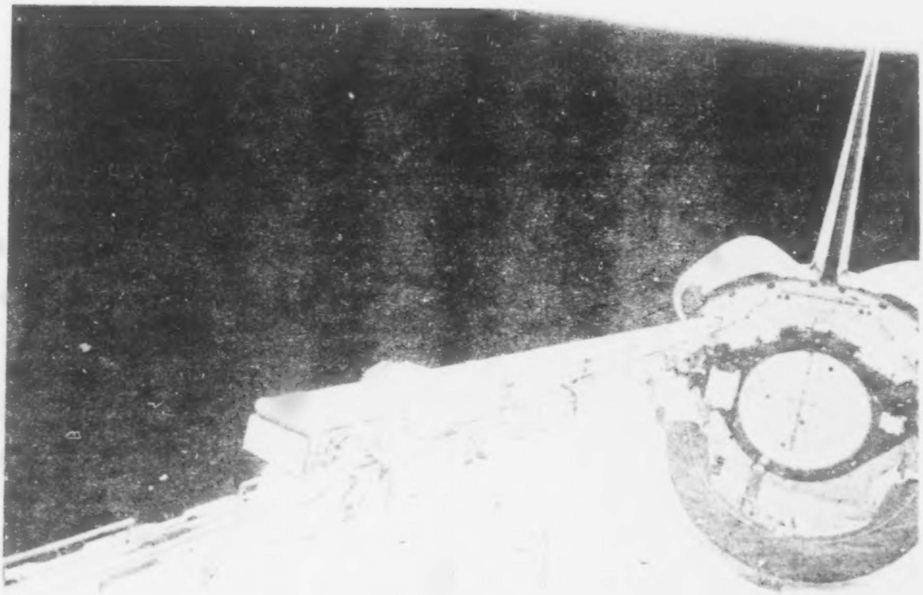
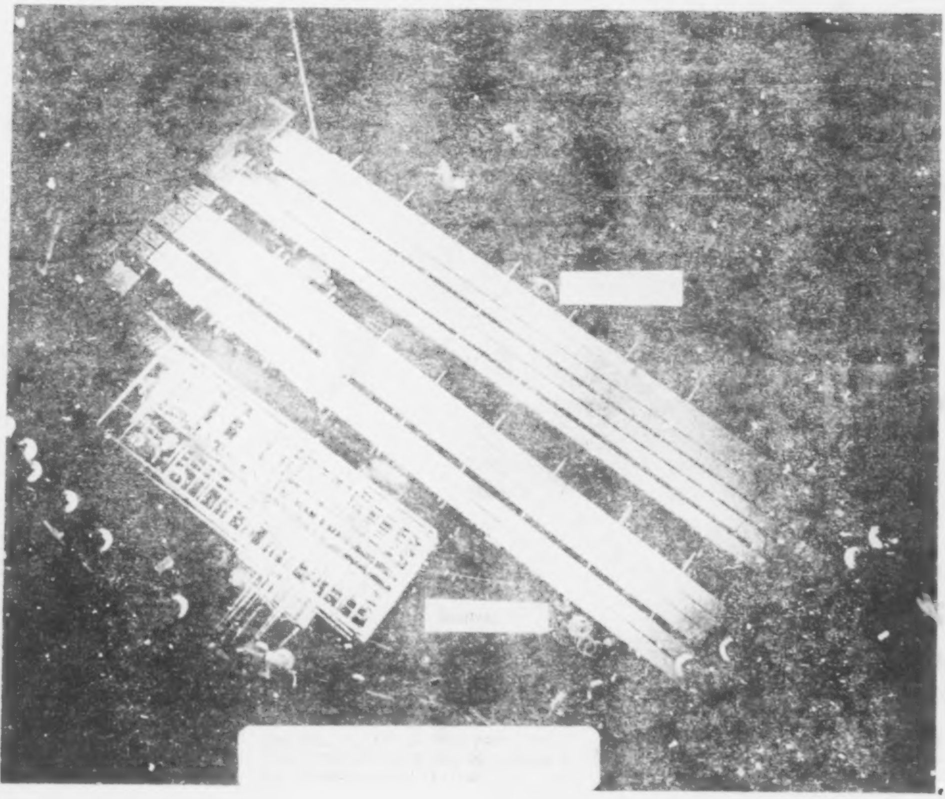
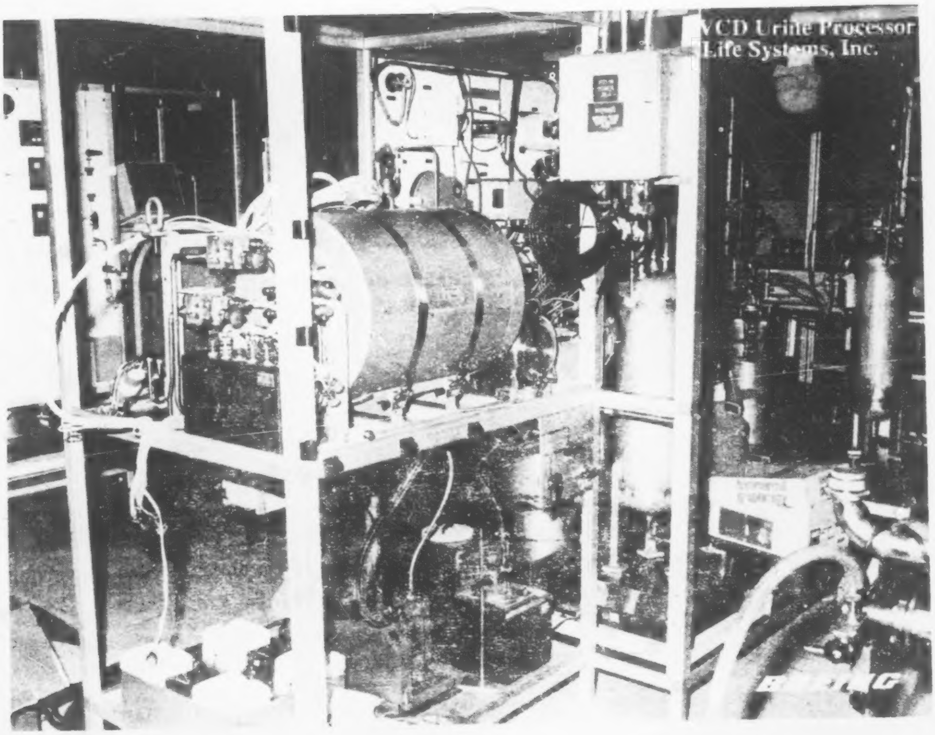
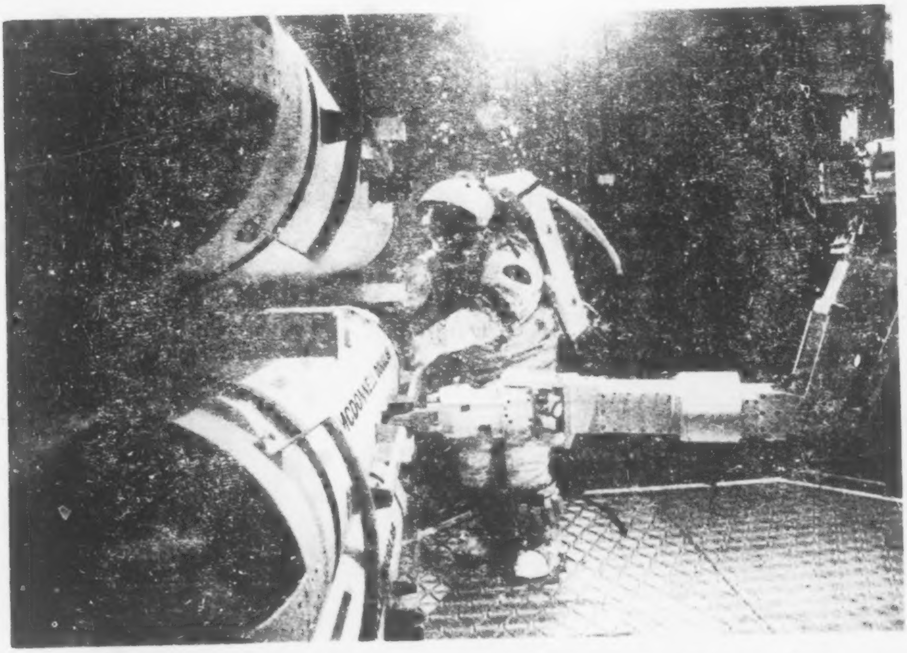


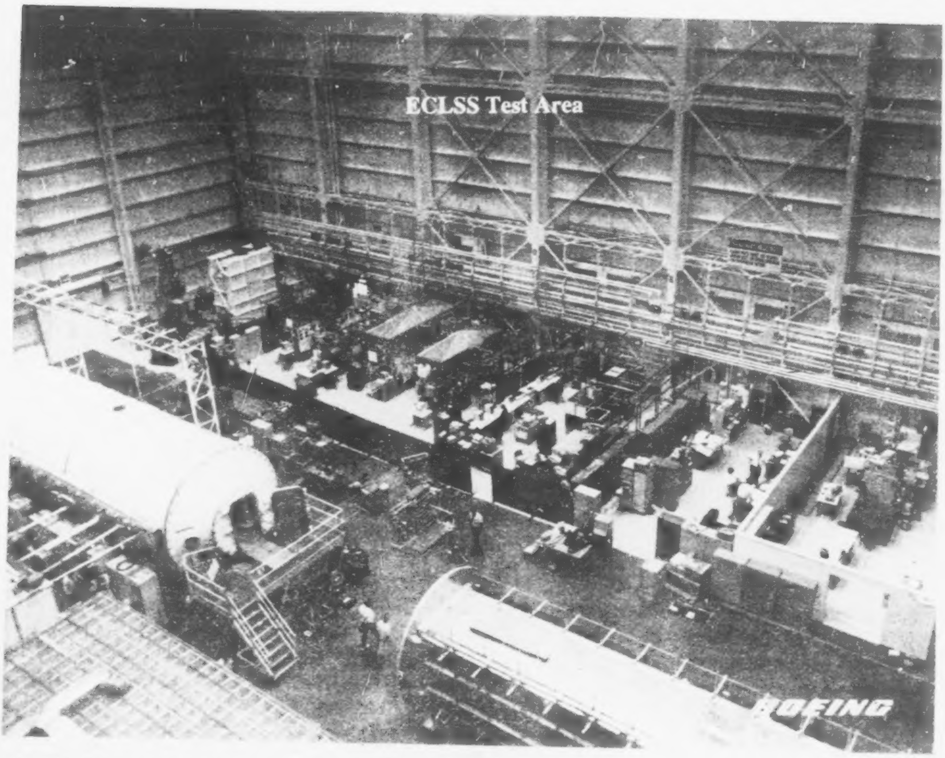
Flight Test of SHARE (Space Station Heat Pipe Advanced Radiator Element)

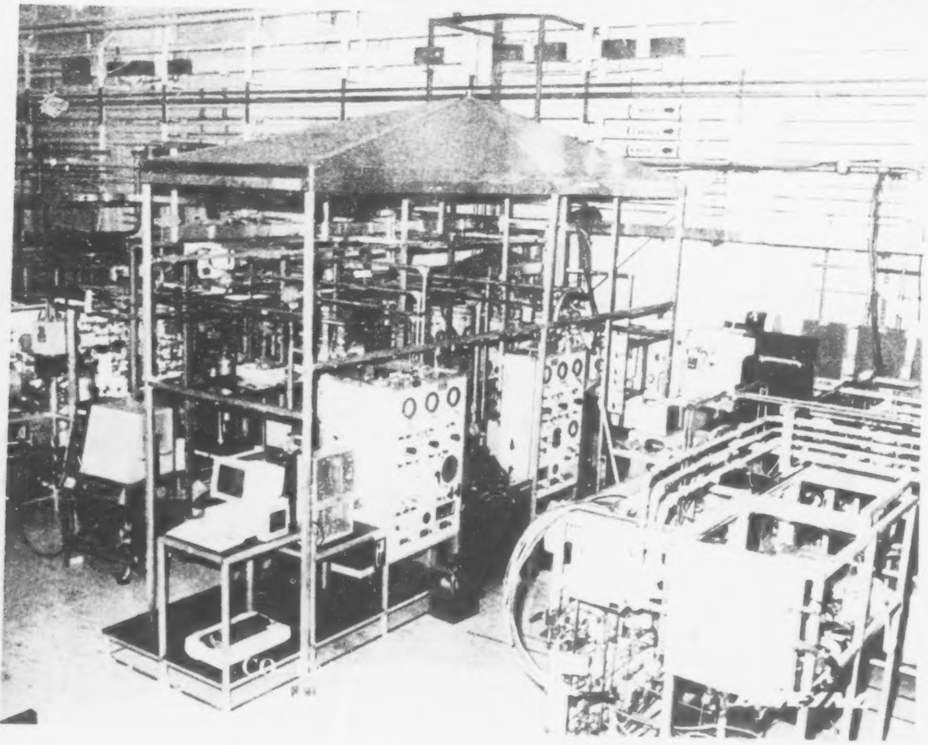


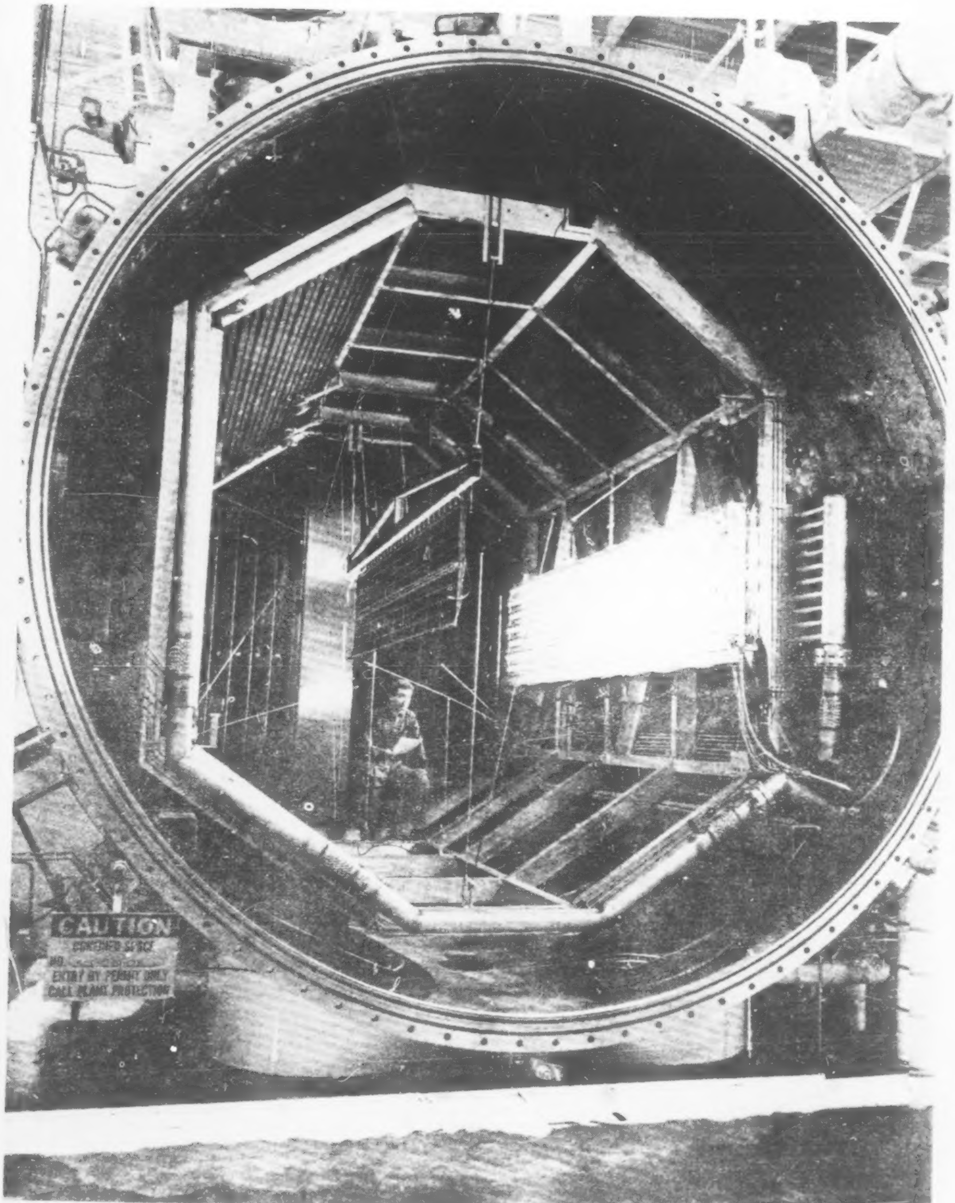

VCD Urine Processor
Life Systems, Inc.



Simulated berthing of propellant tank using both manned EVA and FTS


ECLSS Test Area
BOEING




CAUTION
CONFINED SPACE
ENTRY BY PERMIT ONLY
CALL PLANT PROTECTION

Solar Array Panel Plasma Interaction Test

Responses to written questions submitted by Chrm. Gore resulting from the March 28, 1990, hearing.

Space Station Power

It is my understanding that the baseline for power for the Space Station is still at 75 kW.

Question 1: What options are being considered for increasing the level of power and what are the costs associated with each?

Answer 1: Current station power is baselined at 75kW with 30kW allocated to users. We are studying several power growth options. Early augmentation of solar dynamic power is one option for long term growth of the Space Station. Estimated cost for addition of 50kW solar dynamic power immediately following assembly complete is approximately $1.2 billion for hardware development beginning in FY 1993 and delivery in FY 2000.

Evaluation of the recent proposal to utilize enlarged PV panels to provide an additional 12kW of power has shown that option to be inadequate for Space Station long-term growth. The inherent schedule/technical risk, launch mass penalties and requirements for early funding make it unattractive for only 12 additional kW.

Another option under consideration is to add one extra pair of PV arrays post Assembly Complete. This configuration would place one array, outboard the baseline arrays, at each end of the main truss assembly. The estimated development cost is $183 million for adding 18.5kW to the station power system. In addition, this option would require systems upgrades to the alpha joint, PMAD and TCS. It would also require one additional assembly flight and it would increase reboost fuel consumption by 17%.

Question 2: How does this baseline for power compare to the experiences of the Soviets in their Mir Space Station?

Answer 2: While a complete and thorough comparison is difficult to make, a rough estimate of Mir power output is 18-20kW. It is important to note, however, that the Soviets use different measurement standards than NASA and that Mir is still in an evolutionary stage and will continue to grow.

Space Station Funding

It has been reported that $128 million was cut from the Space Station reserve fund by the Office of Management and Budget in the FY 1991 budget.

Question 3: How will this cut affect the content and schedule for development of Space Station Freedom?

Answer 3: This action reduced the level of flexibility in the Space Station FY 1991 budget, but there was agreement that this had no known direct impact upon the content or schedule for the development of the station. However, it was recognized that the cut could impact our ability to react to unforeseen events and our ability to make changes in hardware/software design resulting from the Preliminary Design Review process. Such changes are a normal activity at this stage of any research and development program.

Funding Cap

Again this year, the President's budget request includes language that would cap the space station's development program at $13 billion in FY 1984 dollars.

Question 4: Do you believe that the Space Station Freedom can be built within that $13 billion limit? Why should the Committee agree to impose this limit?

Answer 4: Yes, we believe that Space Station Freedom can be designed and built within the $13 billion (in FY 1984 dollars) limit, but this is dependent on the concurrent approval of the multi-year authorization and appropriation request which provides necessary funding stability to the program. NASA and the Administration propose both the multi-year funding and a concurrent development program cap, together for stability and cost control purposes, and because it provides an appropriate level of oversight and visibility to development costs.

Question 5: What are the specific items included in this $13 billion cap? Are new initiatives included in that amount?

Answer 5: The $13 billion cap covers the research and development funds for the manned base configuration that emerged from the configuration budget review last fall and funding for the Polar Platform through FY 1990. It does not include funding for FTS, Advanced Development Programs, operations, transportation, construction of facilities, and other user agency and institutional support to the program.

Question 6: Where are we now with respect to the $13 billion cap?

Answer 6: Our current spending is in line with the development program estimate of $13 billion (in FY 1984 dollars). We have been appropriated $3 billion for development, in current year dollars through FY 1990. This equates to approximately $2.4 billion in FY 1984 dollars, or about 18% of the total estimate. The estimate is within the proposed cap even though annual appropriations shortfalls have been significant since the cap was first proposed in the FY 1989 budget.

Space Shuttle Endeavour

The FY 1987, the replacement shuttle, named Endeavour, was funded, using existing structural spares.

Question 7: What is the status of the construction of the new orbiter? Is the contractor staying within cost?

Answer 7: The Endeavour is on schedule for the original delivery date of May 1991, to the Kennedy Space Center. The contractors are currently staying within the available $1.8 billion and are projecting a slight underrun.

Question 8: Does the FY 1991 budget include a request for funds for structural and orbital spare parts for the shuttle?

Answer 8: Yes, there are funds requested to continue both the structural and orbital spares programs.

Question 9: At what point will NASA have to make a decision on the need for an additional shuttle orbiter without facing significant cost increases?

Answer 9: NASA is performing a study to determine the orbiter fleet requirements and orbiter production capability maintenance necessary to support the shuttle flights through at least the year 2015. The study will be complete this September.

Long-Term Shuttle Viability

The Space Shuttle, which is expected to continue operations for the next 15-20 years, is based on early-1970's technology. In your FY 1991 budget, NASA had proposed the Assured Shuttle Availability program, an effort to upgrade that technology, only to have it dropped by OMB.

Question 10a: What specific efforts were being considered in the Assured Shuttle Availability program for upgrading Shuttle technology?

Answer 10a: The Assured Shuttle Availability program proposed last year was intended to support design modifications and improvement programs across all the Shuttle systems to combat obsolescence, vendor capability retention problems, enhancements to safety margins and vehicle performance, as well as to reduce operations costs. Major improvements to Shuttle hardware and facilities considered for the Assured Shuttle Availability program were:

ORBITER

Integrated OMS/RCS
Modern Technology Displays
On-Board/Ground Checkout
Air Data Transducer Assembly Redesign
Electric Power Distribution and Control System Upgrade
Integrated Navigation System-GPS
Integrated Communications System
Advanced TPS
Electromechanical Actuators
Electric APU

Thermal Control System Upgrade
Long-Life Fuel Cells
Lightweight Structures

SOLID ROCKET MOTOR

Asbestos-Free Insulation Qualification
Igniter Joint Redesign
Nozzle-Case Joint Redesign
Redesigned Stiffener Ring
Redesigned Forward Segment Casting Mandrel
Light-Weight Nozzle
High Expansion Ratio Nozzle
HTPB Propellant

SOLID ROCKET BOOSTER

Avionics/Control System Redesign
Laser-Initiated Pyrotechnics
External POD TVC
Hybrid Ringsail Parachute
Composite Nose Cap, ETA Ring Cover
Reusable TPS (With Health Monitoring System)
AFT Skirt Redesign
Soft Pack Parachute
Strengthened Thermal Curtain
Solid Propellant TVC Gas Generator

EXTERNAL TANK

Eliminate ET Range Safety System
Replace Process Chemicals
Composite Fairings, Struts, and Nosecone
Smooth LO$_2$ Tank
LO$_2$ Boiloff Pressurization of LO$_2$ Tank
Helium Augmented LO$_2$ Tank Pressurization
Aluminum Lithium Tanks

SPACE SHUTTLE MAIN ENGINE

Process Chemicals Replacement
Advanced Fabrication Process Engine
Large-Throat Main Combustion Chamber

KENNEDY LAUNCH OPERATIONS

Corrosion Control Program
Hardware Interface Module Redesign
Capital Equipment Upgrades

Question 10b: Why was this program cut by OMB?

Answer 10b: While NASA is not in a position to speak for OMB, it is our understanding that the decision not to include the Assured Shuttle Availability program in the FY 1991 budget was made "without prejudice," and this program may be considered for the FY 1992 budget.

Question 11: In spite of deletion of this program, what on-going improvements are now being made to the Shuttle?

Answer 11: There are a number of improvements now being made to the Shuttle that were initiated over the past several years. These improvements, in many cases, support the goals of the Assured Shuttle Availability program for selected systems.

ORBITER

General Purpose Computers Redesign
Improved Alternate Inertial Measurement Unit
Improved Auxiliary Power Unit (APU)
Improved APU Controller
Carbon Brakes
14-Inch Disconnect Redesign
Orbiter Drag Chute
Improved Nose Wheel Steering System
Solid State Star Tracker
Improved Mass Memory Unit
Extended Duration Orbiter (EDO) Cryo Kit
Enhanced Multiplexer Demultiplexer

SOLID ROCKET MOTOR/SOLID ROCKET BOOSTER

Solid Rocket Motor Contamination Control
New Rayon Source
Non-Asbestos Insulation Studies
Advanced Solid Rocket Motor

SPACE SHUTTLE MAIN ENGINE

Phase II+ Powerhead
Alternate Turbopump Development
New Heat Exchanger (Internal and Single Coil)
Block II Controller
Producibility Program

EXTERNAL TANK

Heater Deletion
Vertical Strut Foaming
Ablator Dam Installation
Elimination of Foam Pre-Spray Runs
New Fire Detector Paper
New Tumble Valve Flight Cover

JOHNSON SPACE CENTER PROJECTS

Mission Control Center (MCC) Upgrade
Shuttle Mission Simulator (SMS) Upgrade
Software Development Facility/Software Production Facility Upgrade
Flight Analysis and Design System (FADS) Upgrade
Information Management Integration Center (IMIC)
T-38 Pacer Classic Structural Upgrade

T-38 Weather Radar/Avionics Upgrade
Shuttle Training Aircraft-4 (STA-4)
Shuttle Carrier Aircraft II (SCA-II)

KENNEDY SPACE CENTER PROJECTS

Launch Complex 39 Operations Support Building
Fiber Optics Installation between Facilities
Launch Processing System Upgrades (LPS)
New Shuttle Processing Data Management System (SPDMS II)
New Launch Team Training System (LTTS)

Extended Duration Orbiter

Last year, NASA decided to incorporate the Extended Duration Orbiter (EDO) capability into the space shuttle program. The basic intent of the plan was to evolve to a 16-day capability by late 1992, subsequently increasing to a 28-day capability.

Question 12: What progress can you report to the Subcommittee on this program? What is in the FY 1991 budget request for the EDO effort? What is the total cost for the EDO program?

Answer 12: The program is progressing on schedule to provide 16-day on orbit capability by March 1992. A major program milestone, the system critical design review, was accomplished in March of this year. The designs of all the major elements including the cryo pallet, new CO_2 removal system, new waste collection system and vehicle modifications are 95% complete. The program is now entering the production and certification phase. Another major program event was the finalizing of an agreement between NASA and Rockwell International (RI) corporation for RI to provide the cryo pallet as a commercial venture. The Endeavour is being scarred to accept the capability to support a 28-day capability.

The FY 1991 Office of Space Flight budget request for EDO is $15 million. Total runout cost for the 16-day EDO program is estimated to be $208 million, including the medical support provided by the Office of Space Science & Applications and the support being provided by OV 105 development.

Question 13: How will the EDO help in the development of Space Station Freedom?

Answer 13: While an EDO is not required for assembly and operation of the Space Station, it would provide us an opportunity to better understand the effects of long duration flight on crew members and provide Station users an opportunity to develop experiments for the Space Station. During man-tended capability, the EDO could increase the pace of the on-orbit outfitting of the manned base laboratories, and extend periods of crew time at the manned base.

Question 14: Will you need an automated landing capability with either the 16-day or 28-day EDO? What would such an automated landing capability cost?

Answer 14: No, a detail review by NASA has determined that the existing orbiter backup autoland capability is adequate for EDO. This conclusion was the same for both 16-day or 28-day EDO capability. We plan to slowly expand our operating envelope to 16-days duration; first at 10 days, then 13 days, finally 16 days. When we are comfortable that we fully understand the operational implications of 16-day missions, we will develop our plan for expanding further to 28-day missions.

The study determined that to modify the various subsystems and avionics involved to create a completely redundant primary autoland capability would cost about $80 million to implement.

Orbital Maneuvering Vehicle

Over the last year, NASA has revised the development schedule for its proposed "space tug", know as the Orbital Maneuvering Vehicle (OMV), significantly changing program management and restructuring its baseline.

Question 15: Is the program requirement for the OMV now firm? When is the scheduled launch date?

Answer 15: The OMV program has been terminated, as outlined in NASA's letter of June 7, 1990, to the Committee.

Question 16: What are the planned OMV payloads?

Answer 16: The OMV program has been terminated, as outlined in NASA's letter of June 7, 1990, to the Committee.

Question 17: What is the projected program cost for OMV?

Answer 17: The OMV program has been terminated, as outlined in NASA's letter of June 7, 1990, to the Committee.

Advanced Launch Systems

Question 18: What is NASA's role in the ALS program? In what areas has NASA taken the lead responsibility?

Answer 18: The Advanced Launch System is a joint DOD/NASA program to develop this nation's next generation unmanned launch system. NASA has management responsibility for the liquid engine systems and the focused technology program (also called the advanced development program). These areas are also particularly critical to support the Space Exploration Initiative. Air Force has overall program management responsibility as well as management responsibility for systems engineering and integration, the vehicle, payload module and logistics. The ALS joint program office is headed by a Program Manager appointed by the Air Force; the Deputy Program Manager is appointed by NASA.

Question 19: What are the major differences between studies related to Shuttle-C and ALS?

Answer 19: Shuttle-C is a near term option for a heavy-lift vehicle. It would make use of Shuttle technology, hardware, and infrastructure, so the up-front investment for development and facilities would be less than that required for on all-new vehicle. However, Shuttle-C would not reduce per-pound delivery costs. ALS is a longer term option for a new family of vehicles with lift capabilities from the 40 thousand class to the 300 thousand class, utilizing many common technologies, hardware components, and infrastructure. It would utilize advanced technologies, hardware designs with significantly greater operating margins, a simplified, streamlined operating philosophy, and major new manufacturing and launch facilities to significantly reduce the per-pound delivery costs. Shuttle-C offers early availability, while ALS focuses on advanced technology and lower operations costs.

Senator GORE. Very well. Thank you very much.

We will concentrate first of all on the recent study and the EVA requirements for the space station as it is currently designed. I guess I would like to say first of all that I kind of saw this as good news and bad news—bad news because of what it indicated about the current state of the program, but good news because it indicated a change in the character of the internal dialogue within NASA.

I commend those, including Dr. Fisher and Mr. Price, who have been extraordinarily candid in stating what I think are not only legitimate but extremely important concerns. And I commend the NASA leadership for almost stifling the natural resistance one would expect to a report like this and eventually coming around to saying well, yes, this is the kind of challenge to our assumptions that we want and that we need.

I think that it illustrates the benefits of new activism by the astronaut corps in the wake of the Challenger tragedy to get very actively involved in assessing factors that may have been overlooked or not analyzed carefully enough the first time around.

So where do we go from here? That is the first subject we will address in the dialogue this morning. First of all, the facts. Dr. Fisher, you and Mr. Price estimated that 2,284 hours of extravehicular activity may well be required because of the needs of maintenance and the failure rate of the many, many parts that you looked at.

There has been some public debate over exactly what these numbers represent. Is it a conservative estimate or a worst case scenario?

Dr. FISHER. Senator Gore, I believe it is neither. I think it is neither pessimistic nor optimistic. It is merely the best answer that we can give you at this time.

We were tasked with obtaining these answers back in December, and we proceeded in a thorough, professional and very credible manner in trying to get, at this interim stage in our report, the best number that we can to provide to NASA. We anticipate the number will change by the time we report in July in the form of a final report. It may well go up; it could go down. We certainly hope that it will go down, but these are the best answers we can give you with the best data available at this time.

Senator GORE. But you have got no intention of bringing it down based on hope alone?

Dr. FISHER. No, sir.

Senator GORE. So you do not view this as a worst case scenario at all. You view this as a right-down-the-middle, most objective assessment that you can possibly make of exactly what will be required?

Dr. FISHER. Yes, sir.

Senator GORE. Dr. Lenoir, I have heard some statements from the NASA top brass that imply that it is kind of a worst case scenario. Have I been hearing that wrong?

Dr. LENOIR. Yes and no. The quotes that are attributed to us on worst case, non-credible, et cetera, were dealing with the New York Times headlines of fatal flaw, and the space station is going to fall down before it is built.

I would like to take issue with not Bill's answer but the implications behind it. We must understand the——

Senator GORE. Before you do that, the quotes did not say worst headline. It said worst case scenario. It is of no importance to go back and dig through that, but it is of interest to me, at least, to understand what you feel about it now. Do you believe their analysis represents a worst case scenario?

Dr. LENOIR. I believe their analysis, as Bill said, represents a snapshot in time of their study, and it is very preliminary data. It is data that they have assembled from the projects that is based on different assumptions. We have not had time, they have not had time, to go back and challenge the inputs and see which ones stand up and which ones collapse when you push on them.

Senator GORE. So you do not really have confidence in their study, then?

Dr. LENOIR. I have the utmost confidence in their study. I do not have confidence that these preliminary numbers in the middle of it will be the final answer, nor do they, I might add.

Senator GORE. Well, they have said that it is subject to change, but based on the assumptions they have made and built into their study do you believe that what they have come out with as of this point in time represents a worst case scenario?

Dr. LENOIR. Yes. I do not think that the real space station as we develop it will be as bad as their numbers indicate. I do not believe that that is a major disconnect between us right now because we are not changing anything. They will proceed. They will deliver their final assessment and some recommendations for how to deal with it.

Senator GORE. Well, the analysis of the station is, according to its authors, based on the most objective assumptions they can come up with. And if there is a mismatch between what they see right now and what is eventually built, that distance can be closed either by changes in the program or changes in the study.

You seem to be putting more emphasis on an expectation that the study will change.

Dr. LENOIR. No, sir. I think that it can be done two ways, neither of which are changes in the study. It is changes that refine the maturity and the quality of the basic data used in the estimations, and that is necessary. That is a part of their plan, always has been. They just have not completed that yet.

The second way is changes in the design that remove requirements for EVA or allocate them to robotics or whatever. That is why Dick Kohrs and I commissioned this study. I mean, we are not at odds with the study; we asked for it.

Senator GORE. It sounds to me like you are at odds with the study, with all due respect. You are treating its authors with tremendous respect and deference and you all are friends who work together and you are choosing your words very carefully. But the substance of what you are saying really does challenge the validity of the results they have produced.

What you are saying is, well, when they take a closer look at the numbers and when they have a chance to build a little more maturity into the numbers they are using, then we are confident their study will come up with different results. I mean, that is what I hear you saying. Am I hearing you wrong?

Dr. LENOIR. That is not incorrect.

Senator **Gore**. Dr. Fisher, how do you react to that?

Dr. **Fisher**. We feel that the numbers that we have given you could move in either direction, and if they move up we will be the first people to tell you. We will give you an objective assessment of that. And if they move down, as we hope they will, we are going to give that our best shot too.

But our job is to get an answer, the right answer, and it may not be a palatable one.

Dr. **Lenoir**. Do not get me wrong, Senator. I expect the numbers to go up between now and July. I do not expect them to arbitrarily come down before they are brought down by design considerations. I expect our assessments to go up. Then we will look at it with a great deal of scrutiny and decide who does this, how do I do it. Is it really credible that thermal blankets need to be replaced this often? Is it really credible that it will take an hour to change a light bulb, or, if so, should I not do that robotically?

That is why we are doing the study, to identify those issues so I can find the real drivers. What are the dozen or so that are driving half of the requirements, and how can I work those off my list? That is the normal engineering process.

Senator **Gore**. There are really two sets of issues. One set of issues involves the substance of these matters in dispute. Another set of issues involves the way NASA as an institution reacts to bad news. That second set of issues has been explored before, and the astronaut corps has been in the forefront of saying hold up here, NASA. You have got to look truth squarely in the eye, and if the news is bad, you have got to figure out exactly how to deal with it.

Even though they are also choosing their words carefully and demonstrating the deference and respect which exists here among all of you, I sense a little frustration that you are not opening your minds to the full implications of what they are having to say.

Is that fair, Mr. Price?

Mr. **Price**. Let me make this statement. In our study, in the first of the three phases that we are going through, the worst thing that we could do is overlook a requirement. We are gathering together all the requirements. We are making sure that everything is accounted for in our process.

We may not have totally accurate numbers at this point in time, and they may change in the next phase because we are going to fact-find them. They may go down, they may go up. Some of the things are relatively stable, like we have counted about 6,000 ORUs. We think that is a relatively stable number.

However, the estimate of the failure rate of each of these ORUs is something that we are not confident of at this point in time. There are different techniques for generating these numbers. At present, the estimate is limited to constant failure rates, which we know in any system is not a true characterization.

Also, the associated work with regard to doing the task at the work site is something that we have to look at further, and, furthermore, the overhead of delivering the agent, whether it be a suited crewman or robot, to the work site is something that we are now investigating.

All of this folded together is a normal process that we go through in NASA. I have chaired this kind of activity before. I have worked in other activities like it in the past, in Apollo and in shuttle. This is normal business, a normal iterative engineering process.

I feel confident that when we come out with our numbers and take them forward that they will be listened to.

Senator **Gore**. All right. I will save my other questions for the next round, but I want to conclude this round on my time by saying to you, Dr. Lenoir, and everyone in the NASA leadership—and you already know this—that our Subcommittee and others in the Congress are going to be listening and watching very, very carefully at how this is resolved because these astronauts have gotten our attention. We believe that the questions they are raising are extremely significant ones and really have to be worked through with the greatest of care.

Dr. **Lenoir**. Could I add one statement? You mentioned that we were very carefully choosing our words. I have to say that we have not always very carefully chosen our words.

As this story began to break last week, it broke on Monday morning, surprised everybody, not that we were working EVA. We knew that. I had a briefing that showed me these same numbers two weeks prior. Monday night we had to put something out because on Tuesday we were going to our House Appropriations hearings and we put out a note to our press people for how to answer questions that we knew would come in that we intended to refute the conclusions in the headlines.

We never intended to attack the credibility of the study or its authors or its leaders. In retrospect, re-reading that, I must apologize and I am the guilty party that wrote the confusing words, and it is possible to read that and to get a different meaning than we intended.

We have no intent to sweep this under the rug. We brought it out. We want the answer. We feel strongly that it is workable and, as I said, in scope, within cost and schedule. There is no major flaw here. We have heard nothing, including the 2,200 hours, which I suspect will go up before it comes down, that does not surprise us, nor does it strike us as unworkable.

We are going to do our best to get to one EVA a month, which says that we want to bring that number down to 150 hours a year, and the next six to eight months will prove whether we get there or not.

Senator **Gore**. Well, that is well and good and I commend you for your willingness to issue that apology. But I would just note again that right here this morning there is still a difference between you all, and it is in the subtleties of how you see the numbers. But there is still a difference right here this morning. We will explore it a little bit more.

Let me recognize Senator Robb.

Senator **Robb**. Thank you, Mr. Chairman. I had to preside from 9:00 to 10:00 so I am sorry I missed the opening statement this morning. I assume that most of the opening statements were devoted to the "New York Times" article and all of the concern that has been generated from it and any other articles.

Dr. **Lenoir**. Not entirely. Most of my statement was with respect to our fiscal year 1991 budget request in the Office of Space Flight.

Senator Robb. Which was the reason you originally thought you were coming here, I suspect.

Dr. Lenoir. We had hoped so, yes.

Senator Robb. I understand how those little surprises crop up from time to time.

Let me just ask a general question, if I may, so that I do not go over ground that may already have been covered.

With respect to the EVA projections—and I do not want to get into specific numbers because I realize those will go up and down—is this a significant change in terms of what you originally anticipated when putting the whole space station program together? In other words, is this an evolution of the understanding of the requirements and whatever changes may be brought about due to the time in space, or is this simply a revelation in terms of the discrepancy between our current experience with EVA-type activity as compared to the very significant increase that is discussed in these reports?

Dr. Lenoir. I do not think there is anything here that surprises us or represents a serious departure from our previous experience base, other than the size. The scale that we are dealing with is very large, roughly the size of the Capitol, and we will know there will be significant external maintenance requirements.

This is our first opportunity to base them on design data rather than early projections and guestimates, and that is the process we are in. I do not believe any of us are surprised at the numbers.

Senator Robb. Is it a fair assumption—I just got the end of your statement a minute ago as I was coming in—that you expect or hope to be able to bring the hours ultimately down to what you would call manageable proportions—I think you mentioned one EVA a month—whatever the case might be? Is that the current thinking?

Dr. Lenoir. Our current baseline would be one EVA per week, which I believe is like 650 hours per year. Our goal is one per month, and I am very confident that we will get under one per week.

I believe we all feel that it is a workable problem and that the list of potential solutions is workable and looks like yes, indeed, there is an answer and a good answer.

Senator Robb. Has this revelation or at least the public revelation and focus on it created difficulty with any of our international partners in this regard?

Dr. Lenoir. No, sir. We have spoken with them. I myself, along with Admiral Truly, spoke with Professor Luest from ESA, discussed this with him. I think frankly they are a little confused about the attention being paid to it, but I am aware of no concerns that they have. They, incidentally, have been a part of this effort.

Senator Robb. Mr. Chairman, because I missed the opening statements, I will conclude at this time. Thank you.

Senator Gore. Senator Rockefeller?

Senator Rockefeller. I have no questions.

Senator Gore. Senator Lott?

Senator Lott. No questions at this time, Mr. Chairman.

Senator **Gore**. Let me go back over a couple that I have, then. What is NASA's time frame for completing its review of the external maintenance requirements?

Dr. **Lenoir**. Our total review will go on continuously throughout the program. The Fisher-Price study is July 1. They will be finished and they will submit their final report. We may ask them to continue.

At that point, the systems integration function will then take those results and continue to work iteratively with the individual designs trying to implement the answers that we come up with, most of which will come from the Fisher-Price recommendations.

Senator **Gore**. Now you sketched in broad outline some of the possible responses to the problems identified in the Fisher-Price study and mentioned the possibility of redesigning the parts of the space station to improve reliability, to make them robotics-friendly, and/or EVA-friendly. Is it fair to assume that with the large number of parts involved a redesign process that had at least two of those three objectives would be somewhat extensive and would be likely to add time to the timetable and money to the budget?

Dr. **Lenoir**. If we set out to do everything, that is possible. We will be looking for standardization. I mean, it may be as simple as saying here are four different standard-sized boxes. If you possibly can, build your hardware to fit inside this and then we only have to do this. And there may be some that cannot.

The real issue is that I believe what we call the 80/20 rule will wind up prevailing—it may be 70/30, we do not know—where 20 percent of those ORUs will drive 80 percent of the requirements for EVA, the point being 20/80 is not the right number but some small fraction will drive a disproportionate number.

We want to identify those where early in the design there is no hard design to change. But we can steer the design in the right direction by saying, hey, of these 20 things I want to make these 10 robot-friendly. Please do it the following way, be more EVA-friendly on these three, change the reliability on these five so they do not fail except one-fourth as much. These two, we do not know how to deal with them; let us bring them inside.

That is why we are working this issue now and that is one of the inputs that will come from the Fisher-Price effort.

Senator **Gore**. Is it likely we will need a new kind of robot?

Dr. **Lenoir**. No. We are looking to make this consistent with our Flight Telerobotic Servicer, which, as I mentioned earlier, is at the beginning of its design program, but at a point of departure. We will continually be evolving and adding technology to keep the United States telerobotics technology moving firmly ahead, and we will add capability. So, to a certain extent, we will always be having a new robot.

Senator **Gore**. Dr. Fisher, Mr. Price, do you all have thoughts on that? If you look at the possibility of moving toward robotics as an answer to this problem you have identified, do you foresee a need for a new kind of robotic capacity?

Mr. **Price**. Senator, I think we have got a good team of robots in our baseline design. Between what is being done at Goddard on the Flight Telerobotic Servicer and what is being done in Canada with regard to the Mobile Servicing Center and the Special Purpose

Dexterous Manipulator, and the experience base that we have on the Shuttle RMS, I think we have got a good infrastructure in place.

There has been a lot of work in the past three to four years establishing this. Beyond that and further in the past, we have had good flight experience with the RMS. We understand how to do this business.

We are moving into another world with regard to a lot more work, a lot more dexterity in the application of robots. It is one of the most popular subjects on the campus today in the engineering schools. I get inquiries every day from different universities and companies that want to get into this kind of business. We are conversing with them. We have networks of information flowing within NASA and within our academic and industrial community.

We will find the kind of technology, given the motivation that I see in our young people today, to solve the long-term problem with regard to robotic application. We have got a good base today and I think we are going to have a good robot and I think we are going to have better robots in the future.

Senator GORE. I might say parenthetically at a hearing not too long ago on robotics I was surprised to see the dramatic increase in DOD funding for robotics and almost no increase on the civilian applications and made the suggestion that we reverse those numbers and then in case of war, draft the robots.

It did not go over well the first time either.

Dr. LENOIR. Part of our long-term look and strategy within NASA is that some of the best and brightest minds in the technical universities are going into the artificial intelligence and the robotics fields, and frankly, we want to attract them into the space program. One way to do that is to make sure that we get out in front on our robotics and our artificial intelligence efforts.

Senator GORE. Dr. Lenoir, you have said that there are a dozen or so items comparable to the ones studied by Dr. Fisher and Mr. Price which are open and currently under review and expected to come together during the preliminary design review in December.

What is the complete list of open items that have been identified by NASA that must be resolved by the December preliminary design review?

Dr. LENOIR. For the complete list I would like to answer that for the record, if I could.

Off the top of my head, I will give you some of the immediate answers. EVA allocation, power allocation. We have recently allocated power to the various constituents and that will be a continuing challenge and we have to make sure that that is coming as we have allocated it.

Weight. We have to stay on top of weight to make sure that individual items do not grow or that will begin to have us individually, flight-by-flight, outgrow the Shuttle and take more Shuttle flights to assemble.

The overall assembly sequence, the integrated way that we will assemble the space station in orbit, that is another one of our issues.

The environmental control system and the timely closure of the two loops in there, avionics. The dozen number was a rhetorical number that was picked out of the air. It may be ten; it may be 14. I would like to do a little bit more looking there and research.

[The following information was subsequently received for the record:]

In addition to external maintenance requirements, the following items are the subject of design trade-off studies now underway within the Space Station Program that are planned for completion in support of the Preliminary Design Review. The results of the studies will be assessed as part of the planned system engineering design convergence process, and are normal activities at this stage of any R&D program.

Assembly Sequence
When to close the Environmental Control and Life Support System Loops
Integrated Structural and Thermal Loads and Dynamics
Microgravity Environment
Orbital Debris criteria
Centrifuge Location
Operations Costs
Firm up User Requirements
Allocations/controls on weight, power, volume, crew time, EVA.

Senator GORE. We will hold the record for you on that point.

What decisions will be made at the preliminary design review? Will this be the point at which NASA will have identified all of the problem areas related to space station development, as well as all of the answers?

Dr. LENOIR. I would like to say yes, but I know from experience that at the time, we will think we have identified them all but over the ensuing three or four years, there will be a few surprises. We will not have all the answers, but we hopefully will have all the questions and have plans to answer all the questions.

In this particular area, at PDR, we would anticipate having a preliminary plan for servicing and maintenance externally that is consistent with the preliminary design at the time, the individual ORU reliabilities, our EVA capabilities, and our robotics capabilities. It is all an integrating function to make sure all of those are simultaneously consistent with each other. We anticipate having that preliminary plan at the preliminary design review, with probably two or three open issues that may require a few extra months to work off.

Senator GORE. Well, is that the point, in December, when you make the design changes? Let us say, for example, that in July, Dr. Fisher and Mr. Price complete their final study and the numbers come out roughly comparable to the ones they now have and it looks like in order to make the space station feasible or make sure it remains feasible you have got to shift toward a heavier reliance on robotic maintenance and the only way to do that is to standardize your ORUs.

Is that the point, in December, when you make the design changes to the station to accommodate these results?

Dr. LENOIR. We will be making some of those continuously. We do not wait until December. We will make them continuously as we decide. But December is the timeframe where—the design changes necessary will not be very severe because, frankly, the design is not very mature in December.

We have preliminary design, which is top-level drawings but no specific details that I could go build the hardware from.

Senator **Gore**. I am not sure I understand that. You say that there will not be many changes because it has not been designed yet?

Dr. **Lenoir**. What I am saying is, for example, within the avionics——

Senator **Gore**. I am talking about the ORUs and the maintenance issue here.

Dr. **Lenoir**. The ORU itself, orbital replacement unit, in a preliminary design sense will be scoped, the size of it, its external interfaces, how much power does it require, what kind of cooling does it require, what is its shape, how do I bolt it in, and what does it do. This will be done and agreed to.

I get inside the box and ask how does it do it. How many printed circuit cards does it have? Does it have motors, switches or whatever. Those details will not be done yet. That is part of the detailed design. So if I change its requirements and say that is too much thermal cooling you require, I can only give you half as much, it is not that I have to go in there and change all the design of the guts of the box; I do it differently from the beginning.

Senator **Gore**. Okay. Dr. Lenoir, maybe I am just slow this morning. We have been surprised by this report and one possible outcome is that NASA is going to have to make some design changes in the space station. That is possible, is it not?

Dr. **Lenoir**. On pieces of the space station, not the whole space station. Let me put it into perspective.

Senator **Gore**. Wait just a second, please. If you have to make some significant changes in the design of major parts of the space station, when will you do that? You will get this report in July. Your preliminary design review is scheduled for December.

When, if they are necessary, will you sit down and make the changes in the design?

Dr. **Lenoir**. If they are necessary, that would be completed and culminated in the December timeframe.

Senator **Gore**. When will we know how much that might change the cost?

Dr. **Lenoir**. Over the three month period following that. And that is not driven just by EVA but these other issues, too.

Senator **Gore**. Can we expect to be surprised in the future with more news of the kind that came out of the external maintenance review?

Dr. **Lenoir**. I certainly hope not, but in all honesty, we consider this business as usual not worth the attention it has gotten. There are lots of other things that we are also working on today that do not necessarily fit together, and those are those issues we talked about. But that is normal at this point in the program.

We are putting them together. They are coming to closure. They do appear to be converging. I cannot promise that none of them are going to be misinterpreted.

Senator **Gore**. Well, these guys do think it is worth the attention it has gotten.

Dr. **Lenoir**. Internally yes; externally, I am not convinced.

Senator **Gore**. Well, I am going to ask for a third round, but I am going to at this point again ask my colleagues if they want to pursue anything here.

Senator Robb.

Senator ROBB. Mr. Chairman, I just had one very brief question with respect to anything that is currently in the budget that might be ultimately made obsolete by virtue of the changes that are going to take place.

Is there anything that would ultimately represent a significant expenditure for which we would have no tangible benefit that is represented in the study that has taken place to date or what has been highlighted to date? In other words, are we going down, with respect to any of the parts, a path that could prove to be a dry hole?

Dr. LENOIR. I understand the question. I cannot think of any. Can anyone else?

[No response.]

Senator ROBB. Thank you, Mr. Chairman.

Senator GORE. I am prepared to pursue this line. Do you still stand by NASA's milestones for the first element launch in 1995 through assembly completion in 1999?

Dr. LENOIR. Yes, sir. Subject, as we said earlier, to the adequacy and stability of the funding as requested, the President's fiscal year 1991 budget request enables that.

Senator GORE. You were quoted publicly as saying in response to this study, "Changes in hardware and systems to drive down EVA maintenance can be accommodated at this time in the space station program without disrupting the schedule, cost or overall architecture of the program." Are you certain of that?

Dr. LENOIR. I am confident of that. I am not certain of anything. But yes, I am confident of that.

Senator GORE. Is that confidence based in part on the assumption you stated earlier, that later versions of this study will certainly show that the current estimate of EVA time is overstated?

Dr. LENOIR. It is based in part on that, although I would not have said it that way. It is based in part on the strong feeling not that it is overstated but that those numbers are right, but that we will have and do have different answers.

Their study has not tried to look at EVA versus telerobotics, et cetera. They have looked at the entire external servicing requirement and said, if I did it all with EVA, how long would it take. We know we are not going to do it all with EVA. I want to be careful with my words. I am not criticizing their work or their number; I am just going beyond that and saying we have different answers.

Senator GORE. But you do not really believe their numbers right now?

Dr. LENOIR. I believe their numbers for external servicing requirements, yes. I do not believe that we will do anywhere near all of those with EVA.

Senator GORE. Well, that is obvious, I think. I think everybody agrees with that. It is not feasible to do 2,200 hours of EVA. I do not think it is feasible.

But, you see, this difference in the way you see the numbers and the way Dr. Fisher and Mr. Price see the numbers seems subtle, but it is really significant. You are telling us here and now that there is probably not going to be any change to the schedule or the cost of the space station because you are confident that whatever changes are needed to deal with the problem that has been identified can be easily accommodated within the current schedule and the current cost.

Now, if you see the study as one which is almost certainly going to change as they look at more mature numbers, to use your phrase, and then identify the problem as one less serious than it now seems to be, then we have to hear your assurances on cost and schedule as being based on an assumption that is not shared by the authors of the study. Do you understand what I am saying there?

Dr. LENOIR. Yes, I understand what you are saying. I am not totally sure that it is not, to some extent, shared by the authors of the study and their team members.

Senator GORE. Well, they are in an awkward position, but let me just ask it in plain English, Dr. Fisher. You all believe this is a little bit more serious than Dr. Lenoir does, do you not?

Dr. FISHER. Senator Gore, we are the messengers. We were asked to find an answer. I have no hidden agendas. I am not an expert in many of the areas that I have been asked to look into. We have done the best work we can. This is the best answer we can give you.

But I will say that none of us on the committee that we have formed have ever felt this represents a show-stopper to Space Station construction, and we have had many chances to discuss just that. But I do believe that the numbers we are giving you are the best we can humanly do at this time, and we intend to continue in an objective fashion to get the best answer we can give you in July.

Senator GORE. Do you feel like Dr. Lenoir is seeing the true meaning of your snapshot as somewhat less significant than you think it is?

Dr. FISHER. I think, Senator, it is important to put these numbers in perspective. As Dr. Lenoir mentioned in his opening statement, a very similar number was arrived at in 1985 and 1986 in the Phase B studies. They had three EVAs a week; we get 3.7. They are really not significantly different. I think it is fair to say no one at Dr. Lenoir's level or at the Johnson Space Center was surprised by these numbers.

In fact, our committee was formed in response to a preliminary study that was done in October under Dr. Bryant Kramer, and his number at that time was 1,732 hours of EVA per year, although admittedly a hastily done study. And it was in response to that and in an effort to try and get a more accurate count that we were chartered.

Senator GORE. Well, all right. I have to say that in order to maintain public support for the space station—and let me repeat I am a very strong advocate of the space station, have been and will remain so; it is the logical next step, whatever our goals in space, in my opinion—surprises like the one which came with this study are disconcerting to the Congress.

In order to maintain our dialogue with our colleagues in telling them that NASA and we are on top of exactly what is happening in this program, we have to have a very clear view. I welcome your statement, Dr. Lenoir, that you are absolutely confident that all the changes that might be necessary to deal with this problem can be made without any adjustment to the schedule or the cost.

I must confess to a little bit of skepticism about that. I hope it is not justified. But we are going to be following it very closely.

Can you give examples—and you can answer this for the record—where NASA has encountered problems at this point in the design review process similar to this EVA estimate and successfully resolved them?

Dr. **Lenoir**. Yes. The one that comes most rapidly to mind is the thermal protective tile on the orbiter. Let me ask Dick Kohrs to talk to that. He was in the program management of the orbiter at the time in the Space Shuttle program.

Mr. **Kohrs**. I do not remember the exact time—Bob Crippen may help me—but it was in the 1976–77 timeframe, just after the Approach and Landing Test (ALT), that the major point in the Shuttle program was that the tile would not stay on the vehicle. An immense effort of the whole NASA community, including all the NASA centers and contractors, pulled that thing together through a systems engineering analysis and a technical analysis, conducted a whole bunch of tests and studies which proved that indeed the tiles would stay on.

That would have been a, I use the word show-stopper, and I do not think the EVA maintenance is a show-stopper in the program today.

Senator **Gore**. On the question of safety, Dr. Fisher, you have been on a space walk, have you not?

Dr. **Fisher**. Yes, sir.

Senator **Gore**. What is your view of the real safety risks involved in EVA? Is that a major factor if we had anything approaching this many hours?

Dr. **Fisher**. No, sir. I think many of these safety issues are overstated.

Senator **Gore**. So that is kind of a red herring when we look at this?

Dr. **Fisher**. I believe so, yes, sir.

Senator **Gore**. Very good. Now, back to robotics for a moment, you expressed great confidence in the state of the robotics program, Dr. Lenoir, and if we go that way you think we will be ready. But in a technical memorandum released this month on advanced automation and robotics technology for Space Station Freedom NASA concluded: "The status of advanced automation and robotics on Space Station Freedom is not good."

They concluded that there is little advanced automation and robotics in the baseline program and the likelihood of its smooth growth and evolution is "problematical". How do we react to that?

Dr. **Lenoir**. I would react to that, and I have had that briefing. That is our Advanced Technology Advisory Committee that we commissioned to do just what it is doing, to look over our shoulders and help us get better.

We think that we have solved most of those. I believe that report that you are quoting from is by now about a year old. Is that Report 9?

Senator **Gore**. It was released this month.

Dr. **Lenoir**. That is Report 9, which is actually close to a year old. I have just had the briefing on Report 10, and the conclusion in that is that we have made a lot of progress and that many of the management issues that had us not paying significant attention in the various areas have been resolved.

Like any advisory committee, they are not completely satisfied and, frankly, they should never get completely satisfied and need to keep pushing on us.

Senator GORE. Well, again let me say your committee issues a technical memorandum on this very point dated March 1990 and they say it is not good. We are asked to accept your assurances that, based on unreleased, later work, it is good. Please submit to us the basis for your conclusion, because your own technical review committee is saying exactly the opposite.

Dr. LENOIR. I have had a briefing on it, but I have not seen the draft. I would be happy to send you a copy of the draft of Report 10.

Senator GORE. It says: "It has been very difficult to maintain a consistent and positive approach to implementing A&R policy throughout the Space Station Freedom program." I will not quote more extensively. "Management has not always been able to support implementation efforts." It is a critical report on the state of your robotics effort.

Dr. LENOIR. I agree. Both Dick Kohrs and I joined the Space Station program last June. We have been on board now less than a year. We found when we came on board that we cared more and pushed harder on robotics than we had in the past, and I believe you see that in the results of the last two consecutive reports and, frankly, this current study is an attempt to put some numbers and identify quantitatively how we unload the EVA and do it more robotically.

Senator GORE. You can answer some of these for the record, if you want. What capabilities will the flight telerobotics servicer have at the time of its first flight test in 1991? Are the 1991 and 1993 flight tests to demonstrate technical capability or determine technological shortfalls?

Dr. LENOIR. The Flight Telerobotic Servicer itself will not fly in the first test flight. It is a technology flight. We are testing parts of it, and a large part of it is the human interface. We will be doing some manipulation and testing out some of the sub-level design to verify that it works.

The first time that we fly something that is approximately total system-like will be flight 2 in fiscal year 1993, and that largely is to verify that the concept and the design will work.

Senator GORE. So again, your statements of confidence in the ability of your robotics program to handle this extra work in case that is the direction you turn are based on a program that is still in the experimental phase and has not been tested yet, is going to be tested at some point in the future.

Dr. LENOIR. Yes, sir. But I can say that about the power system, the environmental control system, all of it.

Senator GORE. Now my final set of questions on this subject before we go to others is on the space suit. If, in spite of new emphasis on robotics, you decide that you have to increase the number of EVAs, you are going to have to look at your space suit issue all over again.

Yet NASA recently decided to cancel plans to develop a new space suit, choosing to rely instead on the shuttle suit for EVA work to be done at the space station. If you have a significant increase in the number of EVA hours, do you see a need to reassess that decision not to develop a new high-pressure suit?

Dr. LENOIR. Last fall, when we killed, if you like, the advanced space suit development program, that removed a budgetary requirement for over $300 million that we frankly did not have, and that helped us solve our financial problems.

When I look at the space suit in connection with this EVA issue, I find that no matter what space suit I use, I will take two people outside who will do six hours of work outside. There will be a certain amount of overhead both before and after, and admittedly in the before timeframe a high pressure space suit will have less overhead than our current Space Shuttle suit. But, either way, the two people going outside and their watchdog inside will lose an entire working day.

Now that may be a little bit too pessimistic for the guy inside, but three working days are my cost. I get in return 12 hours of extravehicular activity—six from each of two crewmen, independent of space suit. So, to first order, the space suit is not an issue.

An advanced high-pressure suit would relieve the requirement for pre-breathe. That is partly a double-booking of overhead. If I design it, I can make if I am careful and really get technology in, I can make it a little easier to use. We have not solved all those problems yet.

Our conclusion was that to build and to maintain the Space Station we did not need a new space suit and that a new advanced high-pressure space suit was not where we wanted to invest $300 million of the American public's money.

Senator GORE. So your view is, even if we have a dramatic increase in the number of EVA hours, you would still cancel the development of the new space suit?

Dr. LENOIR. I would leave it cancelled. If the $300 million were available, I would propose that we take a small part of it and go work the EVA requirements list down by spending money in that technology.

Senator GORE. Dr. Fisher, again you have made one of these space walks. You are intimately involved with this issue. What is your view on that question?

Dr. FISHER. Senator Gore, the issue is really not space suits but the overhead associated with pre-breathe. If I have an emergency outside the Shuttle or the Space Station at the current juncture, I have to sit in a suit or breathe pure oxygen for four to five hours before I can go do anything.

Also, on Space Station if you are going to perform routine external maintenance you would be required to perform the same amount of overhead—dead time if you are in the space suit and probably limited time if you have to be on an oxygen mask with a long cord hooking you to the wall.

There are two ways to solve this problem and I personally cannot imagine going to the moon and to Mars and to the stars with a prebreathe system that has this overhead. The first way is with a new high-pressure suit that will enable you to get into the suit and go outside, thus eliminating the pre-breathe overhead.

The other option is to lower Space Station pressure to 10.2 psi, which is what we do on the Shuttle for our space walks, which would also eliminate most of the need for pre-breathe. I find it very difficult to imagine that we can continue with a sea level pressure Space Station and the current Space Shuttle suit.

Senator GORE. What would be the implications of lowering the pressure in the Space Station?

Dr. FISHER. There are life sciences and user concerns about lowering the pressure and decreasing the pressure from the ambient atmosphere of the Earth, and I am sure there are other concerns that I am not aware of.

Senator GORE. Are you going to rule that option out, Dr. Lenoir?

Dr. LENOIR. We have. There would be significant qualification issues in qualifying the hardware to operate at 10.2 pounds per square inch vice 15.

Senator GORE. So you are going to solve this problem by making all the astronauts sit there for four hours breathing pure oxygen, immobile before every space walk?

Dr. LENOIR. We have some studies that are looking at different ways of doing that, and also I must keep coming back that our real answer is that we do not want to accept that we must have a large EVA requirement. We want to work the EVA requirement openly and honestly down.

Senator GORE. Are you going to go to the moon and Mars the same way?

Dr. LENOIR. That is a different issue. We are dealing here with the Space Station. The exploration is a different issue. It would frankly surprise me if I built a moon base or a Mars base at other than 5 psi, as we did with Apollo and our Skylab Space Station, which would not have a requirement for the life sciences experiments as on the Space Station, merely because I do not want to haul the weight of all the gas to the moon and to Mars.

At 5 psi, I have no pre-breathe issue with any suit.

Senator GORE. Well, when NASA designed the first space capsule there were no windows; is that right?

Dr. LENOIR. I suppose that is what The Right Stuff movie would have us believe. The space capsules that we have flown have always had windows.

Senator GORE. Do you know whether or not the first design had windows or not?

Dr. LENOIR. I have no idea.

Senator GORE. Well, the astronauts tell us that they had no windows and it is not just a fiction made up in the movie, I do not think. I think that is correct. And the astronauts said this is ridiculous, you have got to have a window in there. Does anybody know whether or not that is the case? Well, we will supply that for the record. I will just ask John Glenn when I go over to the floor next time. It is easy enough to resolve.

But the point is that these astronauts have to have a say in an issue like this. What Dr. Fisher, who is a veteran of space walks, is saying on this point is it is ridiculous. He is not using these words; I am. It is ridiculous to contemplate this massive increase or even a significant increase in the number of EVA hours with a system that requires this kind of human stress on the astronauts. That is basically the issue, is it not, Dr. Fisher?

Dr. **Fisher**. Yes, sir. I think the word would probably better be the overhead that it takes out of your time during the work day. It may not take all of your time if you are maybe on a mask that attaches to the wall, but it certainly is a limiter because you have a mask on your face and you cannot be acting in a normal crewman function.

Senator **Gore**. Right.

Dr. **Lenoir**. Senator Gore, we are not insensitive to the requirements of the astronauts or what it takes to operate in space. As you know, Admiral Truly has flown in space, has a good deal of experience. I have flown in space, trained to do the first EVA from the Space Shuttle. Joe Allen and I had independent space suit problems. We never got outside. But we got partway ready.

Bob Crippen, the Director of the Space Shuttle Program, has flown the Space Shuttle more than anyone else, more times than anyone else. We are absolutely not insensitive to the needs and concerns of the astronaut office and are very sensitive to the requirement to maintain our vigilance for safety.

Senator **Gore**. The point I am trying to make with this exchange is not an accusation of insensitivity. Obviously you are sensitive to the experience of the astronauts. The point I am trying to make is a little different kind of point.

I get the impression from your testimony and I sometimes get this from others that the main objective is to make sure that nothing has to be changed, and to defend the proposition that the design and the program as it is currently structured is perfectly capable of absorbing any contingency, any criticism, any problem that comes up, and really everything is just the way it should be.

That is really the problem, and it is a kind of bureaucratic response. I think that one implication of Dr. Fisher and Mr. Price's study is that people would like to break through this shell and hear from the program managers, yes, this may be something that requires us to rethink a good part of this. Privately that is what some people are saying.

I understand that with the budget crunch and all the problems that you encounter on a program this size the natural tendency is to say, no, this really is not a problem at all and everything is just fine the way it is. It may not be, and in order to get it completed in this environment the best strategy may be just to really discard that shell and come in with open minds and say, yes, we are going to work to resolve this in the best way possible.

Dr. **Lenoir**. Sir, we think we do have open minds. I do not agree that we are resistant to change. Dick Kohrs and I will change anything and everything, if need be. We must not forget we commissioned this study. We looked for these numbers. The thing that I do not want to do is to assume prematurely that a change is necessary when I firmly believe that one probably is not.

If we think that there is a change required, we will not hesitate for a minute to make it because we intend to be back here next year, and I would like not to be eating crow sitting here.

Senator **Gore**. I understand, but if you had to state the disagreement simply—and again I am not going to try to put words in the mouths of the people who have worked this problem—when you say a significant change is probably not going to be necessary, I get the impression from people who have looked at the numbers that significant change probably is going to be necessary.

But time will tell. I hope you do not have to eat crow on this.

One final question on this, on the space suit issue. How many space walks can an individual take in the shuttle suit without returning the equipment itself to Earth for servicing?

Dr. **Lenoir**. If I could ask Bob Crippen, we are currently in the process of increasing that. I believe the number is nine, going to 12. Yes. It is currently nine and we are pushing it to 12.

Senator **Gore**. Nine to 12 EVAs?

Dr. **Lenoir**. Yes.

Senator **Gore**. Will transporting an excessive number of suits back and forth from orbit hinder logistical flights needed to service the Space Station?

Dr. **Lenoir**. No, that is within our planning. I also note here that currently, we have not decided whether to come forward with it, but we have the capability to look at pushing that number up to 24 in the Fiscal Year 1991 time frame.

But one of our open issues that we are putting together is the overall logistics requirements, of which this is one part. We do not feel that it is in any way a show-stopper.

Senator **Gore**. Senator Lott, do you have any questions?

Senator **Lott**. No, Mr. Chairman.

Senator **Gore**. Well, let me close out this portion of it by again commending Dr. Fisher and Mr. Price and those who have assisted you in your work. I am very impressed with the professional approach that you have taken to this. It is an issue we are going to be following very closely.

Do you have anything else you would like to add before we move on?

Dr. **Fisher**. No, Senator.

Senator **Gore**. It is my intention at this point to excuse from the panel Mr. David Walker, Dr. Fisher and Mr. Price. Actually, Mr. Walker, we did not direct any questions to you, and I apologize for that. Do you have any comment you would like to make on the interchanges that you have heard?

Mr. **Walker**. Only that I think it is very useful that these things are discussed. I know all the principals involved in this well. I do not believe that anyone is trying to hide problems. I think, as in any organization of this size, there are going to be differing opinions as to how to solve problems.

We are committed as a group to getting the problems solved. We get a lot of help from the Senate and the Congress on that, and we appreciate it, mostly.

Senator **Gore**. I am sure that sums up the reaction of this panel, too.

Let me state again for the record that I am so pleased that Admiral Truly is the one who is going to be overseeing the way this is resolved. I really do think he has an open mind and a proper approach to these things and may actually have been surprised himself at some of the things that have been coming out. I do not know, but I would not be surprised to learn that.

In any event, we appreciate your work, Mr. Walker, Dr. Fisher and Mr. Price. You are excused from the witness table at this time, and if the rest of you will stay there I am going to ask two others to come up and join you—Mr. Joseph Mahon, Deputy Associate Administrator for Flight Systems in the Office of Space Flight, and Captain Robert L. Crippen, Director of the Space Shuttle Program, also in the Office of Space Flight.

I have got a few more questions to begin with on the space station and then we will move to the shuttle.

Captain Crippen, welcome to you. Mr. Mahon, welcome to you. Do you all have anything you would like to say at the outset?

Captain CRIPPEN. No, sir.

Senator GORE. All right. We will just go right into it, then.

As you know, gentlemen, the United States has entered into a series of agreements with Canada, Japan and the 13-member European Space Agency on the development and use of Space Station Freedom. What is the current status of the U.S.-European relationship on the program, particularly after this nation's unilateral decision to re-phase the space station construction schedule?

Senator LOTT. Before you begin, are they going to make a statement or are we just going to get right into questions?

Senator GORE. We are just going to get right into the questions. I asked them if they had a statement and they said no. Now Dr. Lenoir at the very beginning of the hearing had a lengthy statement which covered this too, and it is available here.

Senator LOTT. Thank you.

Dr. LENOIR. I apologize if it was too long. I thought it was short.

Senator GORE. The written statement is long, as is appropriate, and you were appropriately succinct in presenting it.

Dr. LENOIR. Thank you. We feel that we have come a long way. We, unfortunately, did have some disagreements and some rough spots in our relationship with our international partners, in particular the European Space Agency partner, as we went through the painful activities associated with the rescoping and rephasing of the program.

They have requested that we look at launching them earlier than is indicated on our current reference assembly sequence. We have agreed to look at doing that, and we have asked them and they are working with us to explore that. I believe that they feel that our relationships has gotten much better, that they are comfortable with it.

We have not yet acceded that we could in fact launch them early. I think they are disappointed that we cannot agree with that yet. We are continuing, with them, to study that, and that, like most things we have talked about today, will be another item that is not firmly resolved until the PDR time frame, when we understand power availability, our users' requirements for power, and their readiness for launch, as well as the other resources.

Senator GORE. If there needs to be an additional change in the schedule for space station launch and assembly because of the maintenance EVA issue, how would that affect our international partners?

Dr. **Lenoir**. I am not sure it would. It is hard to imagine what the change would be, but if we had to, say, add a flight for maintenance prior to completing the assembly, most likely it would be toward the end of the assembly period and might very well be after they were up.

If we added a flight before they were up, it may or may not delay their flight, depending on exactly what the issue was. If it affected an accommodation they depended on, it might delay them; otherwise, it probably would not because their launch preparation schedule is independent from ours.

Senator **Gore**. Well, if you assume that it will not be a problem, it will not be. But if the problem requires redesign of a sort that delays launch, how would that affect our international partners?

Dr. **Lenoir**. Well, it would delay everybody, including them, by however long the delay was.

Senator **Gore**. How would it affect their willingness to continue participating at the same level in the program?

Dr. **Lenoir**. I would hesitate to speculate for them. I know that they are funded differently than we are, and that they are all different but they have a tendency, especially the Europeans, to essentially be fully funded, and that means that it is more important for them to meet a schedule because if they bust that schedule, it is going to cost more and they may not have more.

So they care, and it would impact them significantly.

Senator **Gore**. Do you get the impression that some of them are kind of at the end of their rope, that they are a little exasperated with the changes thus far and another significant change might just push them over the brink?

Dr. **Lenoir**. I would not say that I would expect that, but it is certainly not out of the question.

Senator **Gore**. What is the total projected dollar value of foreign partner participation in Space Station Freedom?

Dr. **Lenoir**. The Canadian part is somewhat over $1 billion. The European part is somewhat over $4 billion. The Japanese part is somewhat over $2 billion. And that adds up to, roughly, when you look at it, to close to $8 billion.

Senator **Gore**. What is the status of negotiations with the Italians to build a logistics module?

Dr. **Lenoir**. They are continuing. We are making progress there. It is too early to tell whether we will be able to close a deal on that or not, but we have made significant progress toward bringing the Italians potentially on board as a bilateral partner.

Senator **Gore**. There continues to be a great deal of interest in development of an assured crew return vehicle for the rescue of sick or endangered space station crew members. What funding levels have been requested in the fiscal year 1991 budget for the assured crew return vehicle?

Dr. **Lenoir**. As you know, we feel that we require the capability to return the crew at any time if they are left behind at the Space Station, and in the 1991 budget we have requested $16 million for the Phase B effort on the assured crew return. Our current planning is that this summer I will probably ask Admiral Truly to include the assured crew return vehicle as a new start for full-scale development in fiscal year 1992.

Senator **Gore**. What is the current cost estimate for this project?

Dr. **Lenoir**. Somewhere between $1 billion and $2 billion, approximately $1.5 billion. The development is $1 billion.

Senator **Gore**. At last year's hearing on the space station we were told we could expect this to be a new start in fiscal year 1992. You are telling us that is still the case?

Dr. **Lenoir**. That is my intent. I cannot promise Admiral Truly will pass it on or that OMB will buy it, but that is my intent.

Senator **Gore**. And you do consider the assured crew return vehicle a requirement for a permanently-manned space station?

Dr. **Lenoir**. Yes, sir.

Senator **Gore**. All right. Let us move on to the space shuttle, unless our two new witnesses have any comments on the space station before we move on.

Captain Crippen.

Captain **Crippen**. Dr. Lenoir covered all of our significant comments in his opening statement, sir.

Mr. Mahon.

Mr. **Mahon**. No comment, thank you.

Senator **Gore**. All right. Now, to Space Shuttle. It has been reported that NASA is currently considering the possibility of initiating a Shuttle rescue trip of the $150 million Intelsat communications satellite. What is the status of the Agency's review of this possibility and what are the factors involved in your consideration?

Dr. **Lenoir**. We have had preliminary technical discussions with Intelsat and their contractor, Hughes, at the Johnson Space Center last week, and we have had programmatic discussions with Intelsat in our program office in Headquarters this week looking at the potential for doing that.

We have concluded that it is possible and that we will continue to investigate development of options to do that. Considerations would be cost from an Intelsat point of view, the ability to work it into our manifest in a scheduled fashion that meets Intelsat's requirements, and of course there will be technical issues.

At this time, we do not see any technical issues that could not be overcome. It would largely be a cost and schedule issue decided by Intelsat.

Let me ask Crip to add to that, if he would like to.

Captain **Crippen**. No. The timeframe we are working on is to try to come to some definite recommendations in approximately three weeks, and that is in order to meet a board meeting that is scheduled by Intelsat.

Senator **Gore**. All right. Let me see if I understand clearly. Would such a rescue operation be a new flight or combined with a planned flight?

Dr. **Lenoir**. We would be looking at both of those options, or, if it was a new flight then we would look at additional things to fly with it.

Senator **Gore**. What is the cost of an individual shuttle flight now and the marginal cost of each additional flight added?

Dr. **Lenoir**. I am waiting until Mike gets me to the right page. In the shuttle operations, the total cost in fiscal year 1991—that is the year we are talking about—is $286 million, and marginal cost is

$67 million. I am sorry. I got the wrong column. That is $70 million in fiscal year 1991.

Senator GORE. $70 million for an additional flight added. What is the principal driver in the space shuttle system cost structure?

Dr. LENOIR. There are quite a few principal drivers—the flight operations, the launch operations, the solid rocket boosters, the external tank, which as you know is the main part that we throw away every mission, space shuttle main engines, and then the orbiter itself.

Those are the six biggest items, and they are all significant.

Senator GORE. In planning and considering a rescue operation, which number would you be dealing with—the cost of a shuttle flight or the marginal cost of an additional flight added?

Dr. LENOIR. We have not fully investigated that. We have a previous contract with Intelsat. As you may know, they were built to be launched by the Space Shuttle. We have an old contract with them to launch that I believe quoted them a number of $74 million for the whole flight, and multiplied by their fraction. I have forgotten what year that was. That was in 1982 dollars, so that would be $96 million in 1988 dollars.

It is not clear whether either we or they feel that that contract would still apply, but that is another option that is yet a third way of pricing it. My inclination would be that something nearer the marginal cost plus the additional cost would be appropriate.

Senator GORE. Something nearer what?

Dr. LENOIR. Something more like the marginal cost would be more appropriate than the total cost.

Senator GORE. What is the current average turnaround time for the shuttle?

Dr. LENOIR. Even though we have flown nine times since returning to flight, I would not say we have enough flights of a consistent makeup that I could give you an average time turnaround. We have in several cases operated three months in a row on one-month centers, and we have demonstrated that capability. That is our goal, is to get to 12 per year.

Senator GORE. Let me move on to ASRM. Last year, when the Committee approved the ASRM project and worked with the Appropriations Committee to secure funding, the first ASRMs were scheduled for delivery in early 1996. Is that still the proposed schedule for delivery of the first flight set of ASRMs?

Dr. LENOIR. Essentially. We may have just hopped a calendar date here. We are currently showing December of 1995 as our first, so if you are talking fiscal year that is early in fiscal year 1996, but it is also in calendar 1995—essentially the same date.

Senator GORE. All right. What is the status of the ongoing contract negotiations on ASRM?

Dr. LENOIR. As I mentioned earlier, we feel that we have concluded them. On Friday evening the Marshall Space Flight Center and the Lockheed company signed a letter of agreement documenting the terms and we are in the process of drafting up the full-scale contract, however big that is. That will be signed and executed by both parties in the next two weeks.

Senator **Gore**. What impact does the OMB reduction of $60 million in the fiscal year 1990 NASA budget request have on the program schedule and why did OMB make this reduction?

Dr. **Lenoir**. It really has no effect. It was not a capricious reduction, but it was taking into account the fact that we were getting a late start and that as originally proposed we were not going to be signing a contract in December but it was going to be later, and it was allowing for that.

Senator **Gore**. At what point in the Space Station Freedom program will the ASRM be baselined?

Dr. **Lenoir**. We intend to baseline the Advanced Solid Rocket Motors at the PDR time frame. As soon as the ASRM contract is signed and we have a definitive schedule with both NASA and Lockheed's signatures on it, then we will look at that versus the Station schedule, sync it up and baseline it accordingly.

Senator **Gore**. How will this affect the safety of the launch program?

Dr. **Lenoir**. We feel it will enhance their safety, not to imply that we are unsafe now. But the areas in the Advanced Solid Rocket Motor will give us increased safety in margins, and it will automate several of the manually-intensive steps today.

Senator **Gore**. Will the ASRM, with increased lift capacity, reduce the number of space station EVAs?

Dr. **Lenoir**. We have recently completed a study that indicated for assembly only, not for utilization, that if I used the Redesigned Solid Rocket Motors, today's current baseline, it would take 18 Shuttle flights to launch and assemble the space station.

If on flight 7 Advanced Solid Rocket Motors were available and I used them thereafter, that 18 could be reduced to 16.

Senator **Gore**. And EVAs could be reduced?

Dr. **Lenoir**. EVAs would be the same. The EVAs are required to assemble the space station. I largely get my advantages from being able to more fully outfit the modules. I am correct. We did show a small reduction in EVA, but in all honesty it is not a significant driver.

Senator **Gore**. It is a minimal reduction?

Dr. **Lenoir**. Yes.

Senator **Gore**. On Shuttle C, as you know, in its subcommittee markup of the fiscal year 1991 authorization bill the House added $1.1 billion over the next three years for the development of the Shuttle C heavy lift launch vehicle. What is NASA's position on Shuttle C? Is it needed for the launch of Space Station Freedom? If not, what alternatives exist?

Dr. **Lenoir**. The Space Station does not require the Shuttle C. We have done those analyses and frankly tried to justify it, but cannot for Station alone. If one existed, we would use it, but we cannot justify it and say it is required for Space Station.

In fiscal year 1991 we proposed $10 million to continue definition studies of Shuttle C, focused on the Space Exploration Initiative requirements and how they would introduce new requirements, such as a wider-body cargo carrier and cryogenic propellant modules.

Senator **Gore**. Where has NASA placed its highest priority—Shuttle C or the ASRM?

Dr. **Lenoir**. ASRM.

Senator GORE. On Moon-Mars, the issue of launch propulsion systems will be a major factor in any effort to implement the space exploration initiative. What role will the ALS program, as well as the Shuttle C program, have in the President's space exploration initiative effort?

Dr. LENOIR. Both are important and need to be further investigated. In our 1991 request, as I said, we have requested $10 million for continued definition studies of heavy lift, most of which would be Shuttle C type. We have also proposed $40 million for continued technology and testing of the space transportation main engine of the ALS program to ensure that its focus and its schedule supports our exploration initiative.

Senator GORE. How much money has been requested in the budget for the Office of Space Flight for the space exploration initiative?

Dr. LENOIR. $50 million is on the flight systems, advanced transportation, $40 million for the ALS main engine testing, as I said, $10 million for the heavy lift concept definition, and then there is $20 million in the Space Station for exploration-related technologies.

Senator GORE. We will have some other questions for the record, but those are the only ones I wanted to ask in the open session here today. I appreciate all of you taking the time to come here and respond to the questions. I will look forward to continuing this dialogue in the weeks and months ahead.

With those words of thanks, this hearing is adjourned.

[Whereupon, at 11:28 a.m., the subcommittee adjourned.]

MISSION TO PLANET EARTH

TUESDAY, APRIL 3, 1990

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:21 p.m., in room SR-253, Russell Senate Office Building, Hon. Albert Gore, Jr. (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. The hearing will come to order. Later this month, on April 22nd, we will celebrate the 20th anniversary of Earth Day on Earth Day 1990.

It will be a critical date in our continuing effort to focus attention on the ecological system of our planet and how it is in jeopardy.

The Subcommittee on Science, Technology, and Space has tried to play and will continue to play a vital role in that effort. We have convened a number of hearings on global warming, ozone depletion and related issues, and to develop a more complete understanding of the issue of the global environmental change, I, along with Senator Mikulski of Maryland, have initiated a series of round table discussions with leading experts in the earth sciences.

Those discussions have been extremely productive and we hope soon to have some public document that will outline the results of those discussions. In any event, we must ensure that we have the proper framework for documenting global change and taking subsequent actions to protect our environment.

The U.S. Global Change Research Program and NASA's Mission to Planet Earth are welcome initiatives. Both are designed to dramatically improve the scientific basis for understanding our endangered environment.

NASA's Mission to Planet Earth will have three key components:

First, a series of new space platforms, including the Earth Observing System, expected to provide comprehensive long-term observations of this planet's land, oceans and atmosphere.

Second, and perhaps most importantly, the development of an information system to process and distribute the results of these observations and to help us to understand what the observations mean.

Third, the application of this information to a growing earth science research program.

This comprehensive effort is needed to document environmental changes that are occurring, as well as the rate of these changes. We need to learn which changes are driven by human activities and which are the results of natural variability.

We must then develop models that will accurately simulate the workings of the Earth's ecological system, to predict the future behavior of the climate system and the ecological system as a whole.

I am pleased that NASA has made EOS a new start in its Fiscal Year 1991 budget request. The Earth Observing System is the most important new start to come before this Committee in quite some time in my own personal opinion. I do however have some questions about the current proposal which I intend to explore at today's hearing.

For example, we must address the question of whether the current structure for managing the U.S. Global Change Research Program and Mission to Planet Earth is the best way to go about that task. Last year, I questioned Dr. Fisk who will be with us again today, on whether or not it might be a good idea to have a lead agency in charge of the program.

I intend to renew my exploration of that matter today because I continue to believe it is imperative that we know who will be responsible for overseeing all aspects of this multi-billion dollar program.

Secondly, while I strongly support EOS—and let me underscore that fact, I strongly support EOS—nevertheless, that support is based on the need for an increased understanding of the evolution of the global environmental system. We must therefore ask whether the EOS program as currently proposed by NASA will accomplish that objective in the most economical and timely manner.

Are we at risk, for example, by placing all of our eggs in one basket? Also, could some of the data be collected more quickly and at lower cost by using a series of smaller satellites before the EOS system is completely in place sending us data?

Finally, I have raised the issue of data management on numerous occasions in the past, and I am pleased that NASA has demonstrated that it is listening and is attempting to respond to these concerns. They are shared by others, and I believe it is imperative to explore this area of questioning again in the context of today's hearing.

Very simply, we must improve our ability to collect, process, archive, and distribute for analysis the data derived from EOS. This will be our greatest challenge, for in a single year EOS, will double the amount of earth science data that NASA already has in store.

The problem presented by such massive amounts of data is twofold: loss through mismanagement and, more importantly, collection of data that is never used. Last month GAO issued a report on NASA's data management situation, focusing on the storage of collected data and concluded that many of its computer tapes were in danger of being lost, a problem compounded by the lack of an agency-wide inventory of computer tape holdings.

NASA has now begun to address its data management problems, and for this record, let me note that NASA strongly disputes the general conclusions of the GAO in this particular study.

But in any event, NASA's effort to deal with the problems which do exist must continue. As the data volume grows logarithmically with EOS, NASA must prepare for handling that data.

Likewise, NASA should be preparing to use the data management system to better utilize the information that has already been collected.

We need to continue collecting information. We need the kinds of information that EOS will provide, and we need the systems to ensure that the data is distributed and analyzed.

So I look forward to today's hearings.

I have opening statements that Senators Hollings and Pressler would like to have included in the record.

[The statements follow:]

OPENING STATEMENT BY THE CHAIRMAN

There is no greater long-term environmental concern to our Nation and the world than global climate change. As an example of the magnitude of the concern, if the dire predictions now being made about global warming come true, the people of Charleston, South Carolina—like millions of others along the east and west coasts—will be forced from their homes by the rising seas. The devastation would be enormous. The losses would be beyond any comprehension.

The fact is, however, that we do not have a complete picture of where the Earth is heading. Earth scientists simply do not have all the data necessary to predict with absolute assurance that there is a long-term or devastating trend toward global warming. We must pursue ways to obtain more and better information as we proceed to craft policies to minimize the negative effects of global climate change.

The U.S. Global Change Research Program was developed to respond to this obvious need for more information. This multi-agency effort involves NASA, the National Oceanic and Atmospheric Administration, and the National Science Foundation—agencies under the jurisdiction of this Committee—and is critical as we develop a better understanding of our Earth systems. To promote this interagency research effort, the Senate recently approved without objection S. 169, legislation I introduced to ensure that the U.S. Global Change Research Program is a well-planned and well-coordinated Federal program.

NASA's Mission to Planet Earth is an important part of this program and a welcome initiative. Last year, we were fortunate enough to have Dr. Sally Ride testify on the need for NASA involvement in the global change research effort and on the value of this program. Admiral Truly, the NASA Administrator, clearly recognizes the importance of this program.

In this regard, we now have before us a concrete proposal from NASA designed to culminate in the 15-year operation of the Earth Observing System (EOS), which will focus on observing earth from space in order to understand better Earth's climate changes. Just as importantly, this proposal calls for the development of a state of the art information system, ensuring the distribution to researchers of the mountains of new data that will be collected in this program. The sum of this effort will be a better understanding of our Earth system and a more accurate prediction of the future.

Let me emphasize that EOS is not a small initiative. NASA has projected costs over the next 9 years to total some $17 billion. But we must proceed if we are to make headway in our struggle to understand global climate change. As we proceed, it is incumbent upon us to review carefully the structure of this program, to ensure that it will operate in the most cost-effective manner and in a way that will provide us with timely information, necessary if we are to develop policies that will respond in a complete way to the obvious threats to our environment.

I look forward to reviewing this program today with our distinguished witnesses.

OPENING STATEMENT BY SENATOR PRESSLER

Mr. Chairman, I want to thank you for holding this hearing on Mission to Planet Earth. I am extremely concerned about recent climatic and environmental trends that may endanger the health and the future of mankind. Mission to Planet Earth represents an important step towards assessing those trends and developing answers to serious global change questions.

Mr. Chairman, the FY91 budget will usher in an exciting new phase in applying our space science expertise to confront global change issues. I am pleased that the President's FY91 budget request for Mission to Planet Earth funds two promising new starts for the space-based segment of the program.

The first is Earth Observing System (EOS), the set of instrument-packed space platforms that is the keystone to NASA's Mission to Planet Earth. EOS will give us the badly needed long-term data sets about how the oceans, atmosphere, land, and ice interact and affect global climate trends. This is precisely the kind of information we need to find answers to troubling global trends such as global warming and ozone depletion.

The second new start is the Earth Probes program. Earth Probes will complement EOS with a series of a small, free-flying satellites to do Earth studies not possible with the EOS platforms.

The success of Mission to Planet Earth will depend on how well we gather and analyze the satellite data. To that end, it is encouraging that 60 percent of the total costs of Mission to Planet Earth will support data processing, distribution, and analysis.

I am proud that the Eros Data Center in Sioux Falls, South Dakota, will play an important role in archiving the space- and ground-generated data from Mission to Planet Earth. Under a recent memorandum of understanding between NASA and the U.S. Geological Survey, the Eros Data Center has been designated as one of the ground-based systems that will archive the unprecedented volume of data from the space elements. That data will enable the world's scientific community to develop sophisticated mathematical models to predict global temperature change and other climatic trends. Hopefully, these models will guide us in making policy decisions relevant to global change.

I welcome this opportunity to hear from our distinguished panel of witnesses on what is one of the most important space science initiatives of our time.

Senator GORE. We are fortunate to have with us a distinguished panel of earth science experts from the National Academy of Sciences who will discuss their preliminary reviews of the U.S. Global Change Research Program, as well as NASA's EOS program.

We will then be joined by Dr. Len Fisk, NASA's Associate Administrator for the Office of Space Science and Applications and Dr. Robert Corell, Assistant Director for Geosciences at the National Science Foundation, and hear their testimony on the role each agency will play in this arena.

Without any further ado, let me invite our first panel to come to the witness table: Dr. John Eddy, Dr. James Baker and Dr. Byron Tapley, if you three gentlemen would come forward.

Dr. John A. Eddy, of course, is Director of the Office of Interdisciplinary Earth Studies at the University Corporation for Atmospheric Research in Boulder. Dr. James Baker is President of the Joint Oceanographic Institutions, Incorporated, based here in Washington; and Dr. Byron Tapley is the Clare Cockrell Williams Chair, and Director at the Center for Space Research at the University of Texas in Austin.

We are delighted all three of you could join us here today, thank you very much. We will go in the order in which I introduced you and ask you to come forward to the witness table.

I certainly appreciate the contributions all of you have made to this area of study and look forward to your statements. They will be included in full in the record without objection, and if you could present a summary of your statements for us that would be appreciated.

Dr. Eddy, we will begin with you.

STATEMENT OF JOHN A. EDDY, DIRECTOR, OFFICE OF INTERDISCIPLINARY EARTH STUDIES, UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Dr. Eddy. Senator Gore, it is a pleasure for me to be able to testify before someone who is not only environmentally conscious, but also environmentally knowledgeable and one who has led the cause for a better understanding of the planet, long before that was as popular a cause as it is today.

Senator Gore. You are off to an excellent start, Dr. Eddy.

Dr. Eddy. I was coached to say that. I am to give a brief review of our assessment of the U.S. Global Change Research Program as a whole. I currently chair a panel established under the Committee on Global Change at the request of Dr. Bromley to review the plans for the U.S. Global Change Research Program as described in the president's 1991 budget.

The panel is composed of 14 persons with diverse expertise, some of them from the Academy Committee on Global Change, the majority not. So I think it gives a good broad review of this plan, and it works in parallel with the panel that Dr. Baker chairs, addressing more specific issues regarding EOS.

I should like to make three very informal remarks regarding our findings which are preliminary findings with the final report due in July.

The first, I do not think I need to convince the Chairman of, and that is the need for a program like the U.S. Global Change Research Program. For a long time now it has been evident to scientists that we need a better understanding of the earth as a system if we are to respond sensibly to the changes that are occurring. This includes the very difficult task of separating out the human induced changes, what I would call the "marks of man" on the planet, from the normal operation of the system. In order to give this response wisely, in order to act prudently in areas of policy, we clearly need a better understanding of the earth as a coupled system. You have followed the studies that have called for this, and I know you personally have supported them.

Another point is that an essential element of that understanding is not just the building of an observational data base—the taking of observations—but what I would call the real need to put the earth in intensive care.

If we are to determine whether there is something wrong or not, how serious it is, what needs to be done about it, in order to diagnose and prescribe, then we need to be monitoring the vital signs of the planet. I cannot imagine anyone disagreeing with that.

It follows that an essential element of doing that kind of monitoring is a space-born component. The U.S. Global Change Research Program could not exist without a very strong space-born program, and the panel agrees with that, as do I think all thinking scientists who look at the Earth as a system.

The second point I should like to make is that the research plan that was outlined in the president's budget in this gray booklet which we were asked to review contained no surprises. It is the realization of a very pragmatic assessment that has been developed by a broad sector of the scientific community in this country and abroad over the last seven years.

It embodies the general recommendations that have evolved from studies of the National Academy, the distilled product of consensus of hundreds of scientists who deal with various aspects of the earth system.

Moreover, the interagency collaboration that has gone into the plan is real and unprecedented, as is the interaction between the agencies on the one hand through the Committee on Earth Sciences, and the working scientists if you will on the other, through the National Research Council and the NAS.

I question whether the Congress has ever been presented with a program in science that has been as thoroughly vetted as the U.S. Global Change Research Program.

A third point I should like to make is that the program asks for more than funding. It asks for the career commitment of the best scientists we have in a dozen fields. It asks us to put other more private research work aside, and to take up a challenge that now seems to be imperative.

It would start efforts that will commit not only scientists of my generation and younger ones now working but generations that have not yet even entered the field. So it seems to me particularly necessary that we look very closely at how we launch this program, and to make sure that it does go in the right direction. I know that is your concern as well.

For this reason, we have looked at this plan very closely and are going to continue to do that. We are only giving you an interim report, but it makes an interim assessment difficult because it seems so important that this assessment be done right. The panel wants to look at the program in more detail than was available to us in the first round.

Nevertheless, the bottom line message I should like to convey is one of general and positive endorsement, a unanimous endorsement of the panel, that the program as represented in the president's budget is in general and in particular, consistent with the plans that have been called for by this consensus of scientists over the years, and I think that is all I wish to say informally.

[The statement and questions and answers follow:]

TESTIMONY

John A. Eddy, University Corporation for Atmospheric Research

Chairman, Committee on Global Change Panel to Review
U.S. Global Change Research Program
National Research Council

U.S. Senate Committee on Commerce, Science and Transportation
Subcommittee on Science, Technology and Space

April 3, 1990

Mr. Chairman, my name is John Eddy. I am director of the Office for Interdisciplinary Earth Studies of the University Corporation for Atmospheric Research in Boulder, Colorado. I am a member of the National Research Council's Committee on Global Change and the International Council of Scientific Union's Special Committee for the International Geosphere-Biosphere Program. I currently chair the panel established under the Committee on Global Change at the request of Dr. Bromley to review the plans for the U.S. Global Change Research Program as described in the President's FY 1991 budget. This panel, which is composed of 14 persons with diverse expertise in various fields of the earth, biological, and social sciences, is working in parallel with the panel chaired by Dr. D. James Baker. Dr. Baker's panel is addressing the more specific issues raised by Dr. Bromley regarding the plans for the Earth Observation System in the context of the U.S. Global Change Research Program.

The Panel to Review the U.S. Global Change Research Program held one meeting in February, 1990. Working with Dr. Baker's panel, it prepared a preliminary report based on the summary documents describing the U.S. Global Change Research Program and EOS available at the time. This report was transmitted to Dr. Bromley on March 30, 1990. The panel will examine more detailed documentation on the program in the course of preparing the final report. The final report will be available by July 1, 1990.

Mr. Chairman, I believe that the most effective and concise testimony I could give is contained in the portion of the preliminary report prepared by the Panel to Review the U.S. Global Change Program. The report therefore follows:

PRELIMINARY REPORT OF THE PANEL TO REVIEW THE FY 1991 U.S. GLOBAL CHANGE RESEARCH PROGRAM

This preliminary report is based on the FY 1991 summary description of the interagency U.S. Global Change Research Program (USGCRP) issued through the Office of Science and Technology Policy by the Committee on Earth Sciences (CES) on January 29, 1990. The panel's final report will include the review of the more detailed program document, including project-by-project descriptions, that we anticipate receiving in draft form from the CES when it becomes available in early April.

In this report, the panel offers the following preliminary comments.

Does the plan for the U.S. Global Change Research Program address the major scientific uncertainties concerning global environmental change?

The President's FY 1991 plan for the USGCRP will result in a major step toward enabling the advancement of scientific understanding of the global earth system, and in improving our ability to identify trends and anticipate effects in areas of environmental change that are now perceived to be of greatest impact in the next 10 to 100 years. The program, if fully implemented and carried through, will improve the base of knowledge in specifically targeted areas of earth system science where it is presently thin. The program lays the foundation for monitoring the vital signs of the earth and for the development of a substantially improved predictive capability. It describes a scientifically sound and distinctly pragmatic endeavor that is designed to provide the information needed to guide private and public policy in relation to changes in the global environment.

The program includes a combination of space- and ground-based observations to provide global, long-term data sets for detecting change, focused studies to improve understanding of fundamental earth system processes, and analytical modeling to develop the ability to predict future changes. Together, these define a reasoned approach to detecting and interpreting changes in the global environment and to predicting the course of future change. Because of the interaction among these approaches, all three must be developed simultaneously if significant progress is to occur. However, consensus has not yet been reached on the appropriate balance among the approaches, particularly the balance between large, long-term investments required for space-based observations and more immediate investments in research endeavors that will yield information relevant to policy decisions over the shorter term. An interim evaluation of the NASA Earth Observing System in the context of USGCRP--a single initiative that accounts for a large part of the total FY 1991 budget for the USGCRP--is included in a separate report.

To be sure, the breadth, magnitude, and duration of the program, the levels of interdisciplinary and interagency coordination that are required, and the combination of long-term observations, data analysis and dissemination, experiments, and model development pose great and novel challenges to the research communities in many fields, including the physical, biological, and social sciences. There are no precedents, in science, for the development of a predictive endeavor of this magnitude and complexity. Changes will be required in the way that scientific research is traditionally funded and conducted. A new generation of scientists and technicians will need to be recruited and educated to meet and sustain the effort. For a long-term commitment of this magnitude, we feel it is essential that the initial plans be laid with particular care and prudence. For this reason we shall review the FY 1991 plan at the individual program level in the course of preparing our final report.

Does the plan represent the consensus view of the scientific community?

The goals and plans for the USGCRP presented in the President's FY 1991 budget are clearly and consciously consistent with the scientific needs identified in earlier documents by the scientific community concerned with global changes. The documents include the report of the NASA Earth System Science Committee *(Earth System Science: A Program for Global Change*, 1988), reports of the National Research Council that have recommended and defined a global change program *(Global Change in the Geosphere-Biosphere*, 1986; *Toward an Understanding of Global Change*, 1988; and the Space Science Board's *The Twenty-First Century: Mission to Planet Earth*, 1988) and international planning documents for the International Geosphere-Biosphere Program and World Climate Research Program. These documents underscore that if changes in the global environment are to be understood and predicted, knowledge of the earth system, particularly knowledge of the interactions between oceans, atmosphere, terrestrial ecosystems, and humans, must be improved. The USGCRP is a significant step toward the development of such an integrated science of the earth system.

Thus, we conclude that the plan is designed to implement the general consensus of the global change research community about how to attack the critical uncertainties. The plan will not, however, satisfy every scientific interest or concern, first, because of limits in resources and, second, because of the necessity to accommodate technical constraints in making observations, both on the ground and from space. While there is general consensus on the observations required for global change research, priorities among specific observations in light of these constraints are still evolving. In addition, we would expect the plan to evolve as future scientific understanding evolves and to address in the future additional components of the earth system, such as soils, and the diversity of the earth's biota.

Global change is a term that embraces more than climate change and encompasses many far-reaching issues concerning the global environment. They range from changes in atmospheric chemistry and the "greenhouse effect," to reductions in biodiversity from deforestation, to other as yet undetected responses of the earth system to land-use alterations, anthropogenic inputs of pollutants to the atmosphere, oceans, and land, and other human activities. The success of the program will rest on whether it can shift focus, as needed, to address the most compelling of the problems that will undoubtedly unfold. Thus, as the USGCRP is implemented at agency levels through the CES, there will be a continuing need for interactive review by the research community.

What issues will require particular attention in implementing the program?

The panel endorses the goals and general research strategy of the USGCRP as defined in the President's FY 1991 budget document, while reserving comment on individual projects and overall project balance until its final report. The following comments identify issues that we believe will require particular attention as the USGCRP enters into its implementation phase.

- Availability of data pertinent to global change research. The program calls for the establishment of a data and information system that is both a vast enlargement and a great improvement over what is currently available to those who work in earth system science. However, two particular problems may thwart this aim. First, commercialization of the U.S. Landsat and French SPOT remotely sensed satellite data has created an unacceptable financial burden that is essentially precluding access by the research community to these important data. The issue is discussed in the accompanying preliminary report of the Panel to Review EOS in the Context of the USGCRP. Second, problems of the collection and availability of data from vast areas such as those in developing countries of the tropics where pertinent research and data collection are lacking limit the ability to construct global data sets. This problem could be redressed by active involvement in and support for the international counterparts of the USGCRP.

- Availability of human resources to carry out the program. The plans for the USGCRP recognize, appropriately, the vital need to provide opportunities for educating students in order to prepare the next generation of research scientists. Further, in certain areas the program may have to build substantially larger research communities than those that currently exist. Examples are found in the fields of global ecology, hydrology, biogeochemistry, and other areas of interaction that link conventional academic disciplines, and in the emerging area of human interactions. We can assume that increased, sustained levels of funding in these and other areas will add numbers to the present cadre of researchers. However, innovative programs designed to encourage specific careers in interdisciplinary specialties will be required as well. To ensure quality, sustained attention will have to be paid to education and training, and to the rates at which these communities can grow to take up the challenges inherent the program.

- Practical mechanisms for scientific assessment and communication of new scientific information to policymakers. The goal of the USGCRP is to establish the scientific basis for national and international policymaking; a basic tenet of the program is the integration of science into the policy process. Specifically, the plan calls for providing: timely information to Congress, the Executive Branch, and others; periodic assessments of scientific understanding in critical areas of global change; and seasonal, interannual, and ultimately interdecadal projections of selected climate processes. The mechanisms that will be needed to achieve these goals, involving as they do processes of formulating and reviewing consensus, are not yet laid out but will soon need to be. The degree to which reliable projections can realistically be expected and methods for developing and communicating well-reasoned limits on their accuracy will also need to be specified.

- Mechanisms for continued involvement of the scientific community in program planning and review. The vision and conceptual design of the USGCRP has come to pass through a process of synergism linking the research agencies, through the CES, and the research community, through the NRC. As the program is implemented, the continuing, interactive involvement of the research community in a review and advisory role will be no less needed, for reasons noted earlier in this report. New mechanisms may need to be devised to achieve the advisory input of the knowledgeable scientific community during the CES process of developing plans for the USGCRP. To complement the necessary reviews of the overall program, interactive advisory panels that work hand-in-hand with each of the respective agencies involved will be needed to address the complex, cross-disciplinary issues of global change.

- Definition of other programs essential to global change research. The "focused" elements of the USGCRP do not represent the entirety of the research that will be required to meet the aims and goals of the program. "Contributing" programs and additional complementary activities conducted through other federal programs--for example, the program of operational meteorological satellites within NOAA--must also be sustained if the USGCRP is to succeed. It would be self-defeating were the "focused" elements to be funded at the expense of sustained efforts in critical "contributing" programs or relevant disciplinary-based programs that provide the base for scientific investigations. Similarly, it would be counterproductive if large-scale, organized elements of the program stifled support for the innovative research approaches by individual investigators that have always stood at the forefront of scientific discovery. It follows that any critical review of the overall program must be guided by a clearer delineation of both focused and contributing elements. In particular, in future annual plans for the USGCRP, contributing projects essential to the success of the program should be identified more specifically than they are in the FY 1991 budget document.

- International collaboration in global change research. The ability of the USGCRP to secure data that may be available or must be acquired elsewhere in the world, conduct the process research, and build the analytical models needed to meet its goals, as well as the demands of the program on human and financial resources, will require a truly international effort. The International Geosphere-Biosphere Program organized under the auspices of the International Council of Scientific Unions (ICSU) and the World Climate Research Program organized under ICSU and the World Meteorological Organization have these objectives. Through these and other relevant international programs of research, some national activities that parallel those of the USGCRP are concurrently underway. In some other countries, research programs on global change are currently very limited.

  It is obviously necessary for the success of the U.S. program that such national initiatives be encouraged and helped, bilaterally, and that the United States provide appropriate and timely support, including financial support, for the organized international programs as well. The degree to which each element of the USGCRP contributes to or benefits from international efforts should be made explicit, and the cost of supporting international efforts should be a more explicit element in the budget for the USGCRP.

QUESTIONS OF SENATOR GORE AND THE ANSWERS

Question 1. The panel you chair has done an excellent job of reviewing the scientific priorities of the U.S. Global Change Research Program. In Congress we have the difficult job of setting the political priorities in our response to global change. Funding is limited, so we have to choose the most cost-effective strategy for slowing global warming, ozone depletion, acid rain, and addressing other environmental problems. Clearly research is a big part of that strategy, but it is not the only part.

As you know, I am a strong supporter of expanding our global change research program. But I am also sensitive to the concerns of environmentalists and others who look at the tens of billions of dollars NASA is proposing to spend on EOS and wonder if maybe it wouldn't be better to spend the money on scrubbers and solar energy and energy efficiency, to name just a few ways we could reduce the damage we are doing to the environment. For instance, for $10 billion, we could put scrubbers on the 100 coal-fired power plants most responsible for acid rain and still have plenty of money left.

Can you give me concrete examples of where money invested in global change research has provided or could provide clear and direct payoffs in terms of making it cheaper to address the problem of global change?

If you were in charge of addressing global warming and other aspects of global change, how much would you spend on research programs like Mission to Planet Earth and how much would you spend on energy efficiency research and countermeasures to reduce carbon dioxide and other emissions? What do you think are the proper percentages for these different areas?

Answer 1(a). The current evaluation of the US GCRP at assessing the extent to which the program plan will meet the scientific objectives established over the past seven years through the development of consensus within the knowledgeable scientific community. So far, the plan does not deal directly with how the problem of potential global change, including enhanced greenhouse warming, might be ameliorated. What is certain is that an improved understanding of the coupled Earth system, and of the effects of man on the system, will improve our ability to anticipate change, including prudent steps in amelioration. For example, a better understanding of the sources and sinks of radiatively active greenhouse gases would inform the debates regarding controls on emissions. Additionally, long-term observations of the global environment, as proposed in the USGCRP, would conceivably identify emerging changes which, if left undetected, could otherwise be costlier to mitigate or accommodate in the long run.

(b). Trade-offs on expenditures between research to improve understanding of the phenomena affecting global change and countermeasures to reduce emissions of greenhouse gases are difficult to make, requiring that many aspects be weighed. I think all would agree that both are needed, and that to be prudent countermeasures must be based on a foundation of knowledge that includes feedbacks and other effects. It is my personal opinion that we can and should do more in both areas today. I also believe that investments in understanding are a form of insurance when policy decisions are involved.

Question 2. Frank Press recently wrote a concise, yet thorough, two-page article entitled, "What I Would Advise a Head of State about Global Change." In it he covers the causes and effects of global change and provides a strategy to address it. What I find interesting is that Dr. Press, who is himself a geophysicist and head of the National Academy of Sciences, devoted very few sentences to global change research, barely mentioned satellites, and made no mention of Mission to Planet Earth. He seems most concerned about the "small science" aspects of global change research.

Do you think that most American scientists would agree with Dr. Press' emphasis on small science and on taking actions to address the problem rather than just studying it?

Answer 2. Yes. I am confident that Dr. Press did not intend his article to provide his assessment of what balance of research effort is most needed to improve our understanding of global change. I do not think that support for the organized Global Change Research Program is a vote for "big science" as opposed to "small science." The U.S. Global Change Research Program is both. Most of the scientists who will work in the Global Change Research Program will be funded and will work in the mode of "small science"—this is, in small groups: for example, a professor and several students. It is individuals, not large groups, that do truly creative thinking;, so aiming to assure and protect the opportunities for "small science" is a way of maximizing the opportunities for new understanding and new discoveries. These individuals will use data gathered through efforts that might be called "big science." Some data, such as environmental parameters monitored on a global basis over long periods of time, cannot be obtained without large investments. Eventually, the data will be considered, pondered, and analyzed at the scale of "small science." The separation of these two into supposedly competing efforts is more a myth than a reality for those who do research.

Question 3. Dr. Eddy, in your preliminary repot on the U.S. Global Change Research Program plan, you state that "there are no precedents in science for the development of a predictive endeavor of this magnitude and complexity."

Is the proposed plan for the Global Change Research Program what you would consider to be the best scientific approach for addressing the key questions on global change? Perhaps just as importantly, is it a realistic approach?

Answer 3. An attempt to marshall scientific resources to address and improve our understanding in a coordinated program, within the U.S. and internationally, is necessary if progress is to be made in the shortest time. The current plan reflects very closely the recommendations that have been developed by the scientific community through mechanisms such as the National Research Council, aimed at addressing the key questions in a realistic way. Our final report will address this issue in more detail, including questions of appropriate balance among components.

Question 4. Your Committee has concluded that the U.S. Global Change Research Program has the "general consensus" of the scientific community.

In your opinion, what are the scientific objectives of the Global Change Research Program and NASA's Mission to Planet Earth?

If the scientific objectives are met by the Program plan, will the key scientific questions on global change be answered?

Although there is a "general consenus" on the need to expand our Global Change Research Program, I am sure there are dissenters. There is certainly no shortage of worthy research projects. What field of study do these dissenters think should be given higher priority?

Answer 4(a). The scientific objectives are detailed in the documents referenced in our preliminary report. In the fewest possible words, the objectives are to improve scientific understanding of the Earth as a planet, with particular attention to the changes that are now occurring in the system, including those induced by mankind. The EOS component of NASA's Mission to Planet Earth program is meant to support this effort.

(b). The GCRP is designed to answer key scientific questions regarding global change, and particularly those that concern the course of change over the next decades.

(c). The U.S. GCRP is itself a dynamic plan; over time, we should expect that its emphasis change based on what is learned. Consequently, we should assume that worthy research projects that cannot be funded now may be funded in the future. If we identify fields of study that should be given higher priority in the near term, we will identify them in our final report.

Question 5. In your report, you emphasize the fact that because the Global Change Research Program is implemented at the agency level, there will be a continuing need for interactive review by the research community.

What steps must be taken to ensure that the science community has adequate opportunity for the continuing review that you refer to?

Answer 5. The panel has recognized the continuing need for interactive review of the U.S. GCRP by the scientific community outside government, as noted in the preliminary report. This will require a clear delineation of the involvement of the scientific community in developing and reviewing plans for the U.S. GCRP. The report also notes that the need for external, cross-disciplinary scentific panels to advise the agencies on their contributions to the integrated U.S. GCRP.

Question 6. You have identified the problems of collection and availability of data from areas such as developing countries where pertinent research and data collection are lacking, thus limiting the ability of scientists to construct global data sets.

To what extent are foreign governments willing to participate in a comprehensive global change research program? And what is the relationship of the U.S. Global Change Research Program to the International Geosphere Biosphere Program and the U.N.'s Intergovernment Panel on Climate Change?

To what extent do other countries currently share the data from prior, ongoing, and planned earth science activities?

Is the U.S. proposing to bear an inordinate portion of the cost of such an international undertaking? How could the U.S. increase international cooperation and cost sharing?

Answer 6(a). At least 50 nations have endorsed the International Geosphere-Biosphere Program and the World Climate Research Program, of which the US GCRP is a part. At least 20 nations, including all the "world powers", now have national committees that are the counterpart of the US Committee on Global Change of the NRC. To me, this speaks clearly to the interest of these nations to work together to support a comprehensive global change research program. The U.S. has been a leader in the definition of these programs, as I think we should be, but we are not, and cannot, "go it alone." The IGBP was initiated as a nongovernmental, scientists-to-scientist effort to define and initiate international studies that would lay the groundwork for the detailed research needed to understand the interactions between the geosphere and biosphere that come into play naturally and in response to human influences. Consequently, the IGBP is an important element of the international research effort on global change. The UN's IPCC is a related international governmental effort to assess the state of understanding and thus to refine the scientific questions that must be addressed.

(b). The extent of cooperation among countries in earth science activities depends on the field of study. There is, for example, a long tradition of cooperative research in geophysics and in oceanography. International research planning, conduct of research, and sharing of the resulting data have been a tradition in these fields for some time. That cooperation arose from a broadly shared understanding that the critical research in the respective fields was aimed at processes occurring on a global scale. The current awareness should attract additional disciplines to this mode of cooperative work.

(c). Our panel has focused on the critical questions that should be addressed in research, not issues of cost sharing, so I am unable to provide an informed answer to this question. I do not think that the U.S. will be asked to bear an inordinate portion of the cost of the program. Other spacefaring nations, for example, will support and complement the EOS program. At least two other nations currently contribute more than the U.S. to the organization of the IGBP.

Question 7. It seems that some disciplines of science have been slow to get involved in the Global Change Research Program. For instance, the ecologists and social scientists have not been nearly as active as atmospheric scientists and oceanographers, even though they have just as much to contribute.

How can we make sure that all appropriate disciplines are brought into the Global Change Research Program?

Answer 7. It is true that some disciplines are more prepared, or more organized, to participate in the US GCRP. As indicated in a response to an earlier question, based on past experience, as important scientific question are posed, the research community has responded. I would expect that as leaders in the respective fields challenge their colleagues by defining the issues—and as funds for the research are made available through programs such as the U.S. GCRP—that the appropriate research communities will undertake the work. We must also work hard in the field of education to enlist and train the scientists and technicians that will be needed in the future to address these vitally important issues.

Senator GORE. Very good. Thank you. We will hold our questions until everyone has presented his opening statement.

Dr. Baker, we will ask you to go next. Let me preface your remarks with an expression of thanks to you for participating in the round table conversations I alluded to in my opening statement.

I have enjoyed the chance to work with you and look forward to your summary statement here today.

STATEMENT OF D. JAMES BAKER, PRESIDENT, JOINT OCEANOGRAPHIC INSTITUTIONS, INC., ACCOMPANIED BY BYRON D. TAPLEY, CLARE COCKRELL WILLIAMS CHAIR AND DIRECTOR, CENTER FOR SPACE RESEARCH, UNIVERSITY OF TEXAS, AUSTIN

Dr. BAKER. Thank you, Senator. I would like to agree with Dr. Eddy. It has been a pleasure for me to take place in the round table discussions, and I would like to say that it is your leadership and that of Congress that has been crucial in shaping our national efforts in global change. I think this joint effort is crucial as we look to the future.

I am chairman of the Research Council's panel to review NASA's Earth Observing System in the context of the U.S. Global Change Research Program.

As you know, the panel was formed under the auspices of the Global Change Committee at the request of Dr. Bromley, Assistant to the President for Science and Technology.

We just recently issued our preliminary findings as part of a letter report to Dr. Bromley and that report is now available. Our panel has 15 members representing both the science and the engineering community, and it is looking at the issues having to do with the Earth Observing System.

Today I am joined by one of our panel members, Dr. Byron Tapley, who is a member of our review panel, and is also chairman of the Space Studies Board, Committee on Earth Studies, which has been involved in a broader and more detailed review of the proposed Earth Observing System. The Committee on Earth Studies Report is still being prepared and will be published later this summer.

We intend to divide our testimony according to the questions posed in the terms of reference from Dr. Bromley. My statement will cover the scientific relevance of the Earth Observing System and the key issues associated with the Earth Observing System Data and Information System.

Dr. Tapley will address the issues related to the scientific need for simultaneous observations and spacecraft configuration.

Our statements will be based on the preliminary report. We will just give a brief summary and then be available for questions.

The first question that was posed to our panel was the following. Does EOS collect the environmental parameters that are reflected in the U.S. Global Change Research Program priority framework and related policy issues outlined in our changing planet?

Our panel in its deliberations has studied the relevant background documents. We also heard the briefings on the latest status of the program from the different agencies that are involved, and we think we had a good input from the agencies and the scientific community.

In our view, and we have stated this in the report, the Earth Observing System forms an essential part of the total set of space-based measurements that are needed for documenting and understanding global change.

The Earth Observing System does two things for us as a scientific community. One, it provides a kind of measurement technique that is not available in any other way. The simultanteous flight of satellite instruments will give us new information on vegetation, ecosystems, cloudiness, soil moisture, which are some of the key parameters that we have not been able to understand with instruments that have flown in separately.

At the same time, the Earth Observing System will continue those measurements of existing technology where we need long time series from existing technology.

But the Earth Observing System cannot do everything. As you have pointed out many times, we need measurements now in order to begin to understand global change, and so the Earth Observing

System must be looked at in the context of other space-borne measurements.

These include the Earth Probe System for which NASA is also asking for a new start this year, NOAA Operational Satellites, Department of Defense operational satellites and other national research and operational programs.

So when we look at this program we include not only the Earth Observing System, which flies in the late 1990's, but also at the series of satellites which will provide data in the near-term. These include both the Earth Probes and other programs.

We believe that that full set of satellites will provide the data that we need. Both are needed. You cannot do it just with the Earth Observing System. You cannot do it only with the series of smaller satellites.

The second point I would like to address was the Earth Observing System Data Information System——

Senator GORE. If I could interrupt you just briefly on that point. You have listed two categories of information: that which can be collected by EOS beginning the late 1990s and that which can be collected by other satellites sooner.

What about information that is collected in other ways, by ground stations, information that has already been collected and is in storage? I know you are very familiar with the question but what is the context within which that third category of data is related to the first two categories, EOS and new satellites.

Dr. BAKER. I am sorry, I was summarizing a little bit too quickly there. The satellite measurements must be taken in context with measurements on the Earth's surface and in the ocean. Without those measurements we cannot get a full understanding of what the Earth is doing.

So surface measurements are an essential part of that activity, and in fact there are a number of both large coordinated programs that are aimed at both understanding the atmosphere, the ocean and land surface processes that involve heavy involvement with surface measurements.

But it is a combination of measurements that are required. You need the satellites to give the global synoptic view, and you need the land-based measurements to do things you cannot do from satellites.

Senator GORE. So when you were setting up those two categories, you were just talking about the space-based one?

Dr. BAKER. Only the space-based part.

Senator GORE. Sorry, go ahead.

Dr. BAKER. The second part, you are absolutely right, includes existing data. We need to look at existing data to try to find as much information from them as we can, and I think the relevant mechanism is the Earth Observing System Data and Information System.

Data is the key to the program. It is essential that we need to learn how to work with existing data and make sure that they are available to the scientific community. We need to have a way to make sure that the data which are going to come both from the individual satellites and from the Earth Observing System are made available in a way that researchers can use it.

We fully support the NASA planning to date for the Earth Observing System because it is designing a distributed, flexible data system. We have learned in the scientific community that this is the kind of system that we need to work with data.

We feel that the connection with the academic community and with industry has been good, but it needs to continue a close interaction with NASA as the data system develops.

It is also essential that the connections with other agencies continue to be strong, particularly NOAA and USGS because they are major players. We have noted as you have, and I think it has been an important point for a long time that it is difficult for the scientific researcher to get access to Landsat and similar data because of the cost of the data. Something needs to be done about that.

We also notice that the storage media for the Landsat data and other long-term data sets are deteriorating. We need a way to transfer the relevant data to a more secure and accessible data base.

Let me just summarize and then turn to Dr. Tapley. We believe that the combination of EOS and the Earth Probes will provide both the near-term and the long-term information that we need for the space-borne component to study global change.

We are looking forward to working with the agencies and Congress to see that this happens. Thank you.

Senator GORE. Thank you very much. Dr. Tapley, welcome.

Dr. TAPLEY. I am very pleased to be able to address this hearing. I share my colleagues appreciation for the attention that you have given this important issue. The extent to which you have familiarized yourself with the complex interactions associated with Global Change and the actions required by the federal agencies to address these issues make the opportunity to address this hearing a particularly important dialogue. Measurements from a satellite sysem, such as the proposed Earth Observing System, are viewed as a crucial component of the overall Global Change initiative.

The two specific points that I would like to address have to do with the requirements for measurement simultaneity and the impact of these requirements on the size of the spacecraft. These are two separate questions that were addressed to the panel study.

The simultaneity issue is a major driver in shaping EOS. The panel has looked fairly carefully at the concepts of simultaneity to ascertain what this concept implies. In this study, we have separated the measurement requirements into time sequence requirements and spatial coverage requirements.

We have considered the question with regard to the need for instrument simultaneity and the need for scientific measurement simultaneity as drivers for the sampling issue. The conclusion that we have reached after the study is that there are strong arguments for simultaneity in the overall measurement process.

The panel concludes that these strong arguments are based both on (1) reasons for ensuring the quality of the measurements, for example, the need to make ancillary measurements along with the primary measurement to be able to get the measurement accuracy that you would need from a given sensor, and (2) the need to be able to make measurements from a number of sensors at the same point to address specific science issues.

With the conclusion as outlined in the report, that simultaneity is an important issue, where the various shading of the concept is still being refined, there is compelling evidence that there are arguments for simultaneous measurements, from an adequate number of sensors, that the platform issue can be considered under the guideline that simultaneous measurements is an important requirement.

Given this conclusion, we turn to the issue of the large platform versus the small platform. In the presentation to the panel by NASA, three configurations were considered: the large platform, an intermediate size platform, and a small platform. These configurations were based on the size of the launch vehicle. With the science driver requirements for putting together a minimal subset of sensors to ensure simultaneous measurements, the panel concludes that there are compelling reasons for at least one series of the large platforms.

The second platform is still subject to the final sensor selection, but there is fairly compelling reasons, based on simultaneity, for flying one sensor complement on a large platform.

We believe that the measurement requirements alone, based on calibration issues and the need to get the adequate ancillary data for collecting the primary measurement would require that at least the first sensor complement be flown on a large platform.

The discussions also with regard to trying to fly the same sensor complement with a series of smaller platforms has led to the conclusion that this scenario is more costly and is operationally intractable. To achieve the objectives of the mission, it would require 36 satellite launches using the small platform option. The on-orbit requirements for flying the satellites in a sufficiently close cluster to achieve some degree of measurement simultaneity, appears very difficult from an operational view and it appears to put a major burden on the data collection system.

The conclusions of the panel at the present time and in the preliminary report, are that the arguments given by NASA for the large platform are reasonably well substantiated for the first platform. The second platform is still an open issue.

The point that Dr. Baker made earlier that the mission concept, as presented, which is based on a large platform mode supplemented by the Earth Probes series is appropriate. However, there are a number of important issues that the Earth Probes would address.

One of the major roles for the Earth Probes is based on the point, Senator, that you alluded to earlier, the importance of the historical measurements. There are two reasons why we would want to look at the data we have in our current data base. We have to remember that when we measure global change, this requires a measurement at one point in time and a measurement at another point in time to be able to see the change. The earlier we can get an adequate and calibrated data base, the sooner we will be able to have some perception of the change.

So it is extremely important to an early measure of global change that we use the data that are in the current archive and that we do what we can to supplement that current data by adding to it with the Earth Probe line, between now and the time the first EOS platforms are orbited.

There are a number of measurements that are currently planned in the NASA program: the altimeter measurement sequence, the scatterometer measurement sequence, the tropical rainfall measurement sequence. All of these are important measurements that must be made in order to get the proper baseline measurement. That is the required baseline measurements to interpret EOS measurements early on in the mission. The longer the time series, the better the quality of the measurements in the time series, the quicker we will get a handle on the parameters we are trying to measure.

We see the Earth Probe as an extremely important component of the overall EOS measurement process and the probleline should be given attention and reasonable funding vigor in the early part of the mission.

In addition, in our preliminary report, we support the current platform configuration for the A Platform series. The question for Platform B, or the second series, would require knowledge of final selection of the instruments prior to forming an opinion. I will stop at this point and turn it back over to you.

In closing, I again express my appreciation to you for your interest and attention to this extremely important issue.

[The statement and questions and answers follow:]

TESTIMONY OF D. JAMES BAKER
AND
BYRON D. TAPLEY

Chairman and Member, Panel to Review NASA's Earth Observing System in the Context of the USGCRP

National Research Council

Mr. Chairman, my name is D. James Baker. I am the President of Joint Oceanographic Institutions, Inc. in Washington, D.C. and I hold a PhD degree in experimental physics. I am currently chairman of the National Research Council's Panel to Review NASA's Earth Observing System in the Context of the USGCRP. The Panel was formed under the auspices of the Committee on Global Change to participate in preparing a response to a request to the National Research Council from Dr. D. Allan Bromley, Assistant to the President for Science and Technology.

The Panel recently issued its preliminary findings as part of a letter report to Dr. Bromley, dated March 30, 1990. The membership comprises 15 persons with diverse expertise in the scientific and technical disciplines pertinent to the task.

I am joined today by one of the Panel members, Dr. Byron D. Tapley. Dr. Tapley is the Director of the Center for Space Research at the University of Texas at Austin and he holds a Ph.D degree in mechanical engineering and astrodynamics. In addition to serving as a member of the review panel for the NASA Earth Observing System, he is also chairman of the Space Studies Board's Committee on Earth Studies, which has been involved in a broader and more detailed review of the proposed Earth Observing System. The Committee on Earth Studies report is still being prepared and will be published this summer.

Mr. Chairman, Dr. Tapley and I intend to divide our testimony according to the questions posed in the Terms of Reference from Dr.Bromley. My statement will cover the scientific relevance of the Earth Observing System and key issues associated with the EOS Data and Information System. Dr. Tapley will address the issues related to the scientific need for simultaneous observations and spacecraft configuration.

PRELIMINARY REPORT OF THE PANEL TO REVIEW NASA'S EARTH OBSERVING SYSTEM IN THE CONTEXT OF THE USGCRP

This report is based on a review of the most recent NASA documentation on the current status of the proposed Earth Observing System (EOS), including the *1990 EOS Reference Handbook*, several other documents, and oral briefings. In particular, the panel benefitted from the deliberations of the Space Studies Board's (SSB) Committee on Earth Studies (CES), which has been evaluating the EOS initiative since June 1989. The final report from the SSB/CES evaluation effort, which is being undertaken in a broader context than this panel's review, will be issued in the summer of 1990. The panel also received a copy of a letter from the President of the American Geophysical Union to NASA outlining the results of an AGU review of EOS, a draft letter from the Chairman of the NASA EOS Payload Advisory Panel, as well as the latest information on plans for the U.S. Global Change Research Program (USGCRP).

In the EOS program, NASA proposes a major step in the evolution of the science and technology of global remote sensing. The objectives of EOS are to integrate a number of related--but previously unavailable or disparate--space-based measurements into one continuing system and to greatly enhance research capabilities, while providing a test bed for the development of the next generation of operational, earth-observing instruments and measurement techniques. Consistent with the needs of the USGCRP, EOS is designed to yield a long-term, continuous set of high-priority measurements on a global basis. The measurements will be combined for the first time with other important data obtained from space-, suborbital-, and surface-based sources into the EOS Data and Information System (EOSDIS). The comprehensive contents of the EOSDIS are intended to enable the scientific community to document, monitor, and model environmental change, to broaden our understanding of the entire earth system, and to improve predictive capabilities. Both the EOS spacecraft and EOSDIS are planned as interdisciplinary, interagency, international endeavors, all of which are essential features of the USGCRP.

As indicated below, the panel expects to receive more detailed information on several key aspects of the proposed program in the preparation of its final report. In this preliminary report, we summarize some of the most important issues raised in the terms of reference and note in particular those areas that require most immediate attention.

1. Does EOS collect the environmental parameters that are reflected in the USGCRP research priority framework and related policy issues described in "Our Changing Planet"?

The 1990 NASA report, *EOS: Mission to Planet Earth*, together with the agency's predecessor documents on Earth System Science and the Earth Observing System and a series of National Research Council reports, establish the scientific and technical requirements for the development of space-borne, earth-observing instrumentation. The most recent NASA documents emphasize a close connection between the specific research priorities of the USGCRP and the interdisciplinary science objectives of EOS. Long-term, continuous, space-based observations are central to meeting the scientific and policy objectives of the USGCRP. There appear to be no insurmountable scientific or technical barriers to implementing the goals and objectives of EOS. The panel will address the responsiveness of EOS to the specific USGCRP priorities in its final report of July 1, 1990.

The EOS forms an essential part of the total set of space-based observations needed to improve scientific understanding of global change. Not all the environmental parameters required for understanding global change, however, can be measured by the EOS spacecraft or by NASA's international partners in the program. Therefore, EOS must be viewed in the context of other contributing activities. Some parameters must be measured by space-borne instruments in other orbits, and many parameters must be measured on the surface of the earth or in the ocean. The full set of space-based observations that will contribute to improved understanding of global change are expected to be made by EOS, other NASA research programs including the proposed Earth Probe series, NOAA's operational satellites, and operational and research satellites launched during the next decade by other nations. The observational strategy for this overall system, first presented in the 1986 NASA study, *From Pattern to Process: The Strategy of the Earth Observing System* by the EOS Science Steering Committee, should be periodically updated.

The complete set of measurements to be made from EOS spacecraft will depend on success in the development of the respective instruments and on other factors. The set of instruments being prepared for flight appears to be capable of providing a comprehensive set of measurements of high priority environmental parameters. Our preliminary review, however, suggests that two key parameters--soil moisture and global biomass--may not be adequately measured. This is because the only instrument with the potential to measure them from space--the U.S. synthetic aperture radar (SAR)--is not included in current budgetary planning. While these data can be gathered on the ground, observations from space would provide the only possible means for obtaining such data in a long-term continuous set on a global basis. Engineering considerations suggest that the SAR instrument is not compatible with the multi-instrumented EOS platforms. Therefore, the potential contributions of a free-flying SAR mission should be carefully considered in the context of global change research.

2. EOS is premised on the assumption that it is essential to collect global data on various environmental parameters simultaneously. How important is data simultaneity to the ultimate utility of the data? Can the requirement of simultaneity be applied more narrowly than proposed?

As noted above, previous NRC and agency reports have laid out the initial strategy for a measurement program for the study of global change. In the *Mission to Planet Earth* volume of the 1988 Space Studies Board report, *Space Science in the Twenty-First Century*, it is emphasized that the required measurements must be "...*global and synoptic*, they must be carried out over the *long term*, and different processes... must be measured *simultaneously* (to a degree dependent on the rates involved)."

To clarify the discussion of simultaneity, the panel defines observations taken at the same time as "concurrent," and those acquired at different, successive times as "consecutive"; observations of a common area obtained through the same view path are termed "coincident," whereas those taken through different view paths are termed "congruent." The most demanding requirement is for observations that are both concurrent and coincident; the least demanding, for consecutive, congruent observations.

Several lines of argument are considered in addressing the issue of the desirability of concurrent, coincident measurement of parameters. First, the techniques for making some measurements depend on environmental conditions that can be sensed with companion instruments. For example, data from surface imagers must be corrected for atmospheric moisture. Environmental conditions have different degrees of persistence, but some, such as atmospheric moisture, can vary on time scales of seconds to minutes, so that companion instruments of this type should fly on a concurrent and coincident basis. Where concurrent, coincident measurements are required but not made, no amount of subsequent data processing can recover the full information. Second, understanding certain natural processes may require measurements of several different, simultaneously interacting parameters, such as surface winds, ocean currents, and ocean color. Third, merging congruent streams places additional technical and financial burdens on ground-based data management and computational systems over those that would be present if the data were taken coincidently. Fourth, engineering considerations--such as the availability of launch vehicles, onboard electrical power, viewing angle, and data transmission capabilities--affect decisions on spacecraft size, complexity, reliability, and cost. There may be systems advantages to larger spacecraft that make possible simultaneous measurement with a number of instruments. There may also be scientific and engineering disadvantages, however, such as requiring all those instruments to fly on the same orbit, which may not be optimal for some measurement objectives, or increasing the risk of long gaps in critical observations by the lack of flexibility in the case of sensor failure.

There are strong arguments in favor of simultaneous measurements in certain cases. For EOS to provide the data needed to understand global change processes themselves, and not just to document boundary conditions, it must be able to conduct concurrent, coincident imaging surveys at variable spatial and spectral resolution. These arguments appear convincing for several subsets of instruments proposed for the first platform series. The panel will continue its review of the simultaneity requirements and will provide a detailed assessment in its final report.

3. Depending on the outcome of the question of simultaneity, are the EOS platforms, as currently configured, the optimal means for collecting data, or are there better alternatives that are more cost effective or timely? These alternatives could include, for example, smaller multiple platforms flying in formation or additional near-term precursor missions that are capable of flying subsets or preliminary versions of EOS instruments.

A number of scientific, technological, and programmatic tradeoffs are involved in evaluating satellite missions of divergent size and scope. Several configurations have been presented by NASA to the panel, ranging from the agency's baseline configuration of two platform series (with three replications each) to an observing system with the equivalent instruments comprising 36 small spacecraft.

The simultaneity arguments appear to support the development of at least one large spacecraft series and they generally reject a system configured exclusively of numerous smaller spacecraft. The instruments proposed for the second platform series have been peer-reviewed and are equally justified scientifically, but they may not all need to be on a single large spacecraft. On the other hand, there may be engineering and operational advantages to having identical space platforms and these arguments also need to be considered.

NASA's current science strategy does not fully address the issue of continuity of key data sets throughout the 15-year lifetime of the mission. How will data be provided to researchers in the event of the premature failure of a platform or of individual instruments? For example, NASA considers the Moderate Resolution Imaging Spectrometers, MODIS-N and -T, as the "mission critical" instruments for the first platform series, and the agency is prepared to delay the mission until these instruments are ready. The panel agrees with this assignment of priority, particularly because of the key role of the MODIS instruments in documenting change in terrestrial and oceanic ecosystems, and because they are part of a suite that will provide significant benefits from simultaneous measurement. But what would happen if a MODIS or a key complementary instrument were to fail? These and other aspects of contingency planning, including the impact of alternative satellite configurations, are still under review. Additional documentation on contingency planning is needed to answer questions of this kind before such issues can be resolved.

At this time, NASA's cost estimates are not sufficiently precise for one to conclude whether a configuration of one large spacecraft with several smaller complementary spacecraft is more or less costly than the proposed two large platforms. The NASA cost estimates for an observing system consisting only of small spacecraft launched on Delta rockets, however, indicate that such a configuration with an equivalent number of instruments would be roughly 50 percent more expensive than either of the other two options.

The first of the EOS platforms is scheduled to be launched in 1998. In the interim, significant opportunities exist for gathering key global change data through a number of U.S. and foreign research and operational satellite missions, including the Earth Probe series. Also, the agency plans to develop the EOSDIS as early as possible in order to make available to the research community historical and contemporary data sets that can be used to experiment with DIS prototypes in evaluating operational concepts.

An important concern in the near term is the discontinuity of key measurements such as global stratospheric ozone levels, the Earth's radiation budget, and the biological productivity of the oceans, made by satellite missions launched in the 1980s. The Earth Probes line can provide opportunities for extending those measurements until acquisition of the data sets is resumed by the EOS spacecraft. The Earth Probes will also provide global information on parameters not measured before, for example, on Earth's gravity, which must be accurately known to infer ocean currents from satellite altimeter data. A precise determination of ocean currents is important for understanding how heat is redistributed across the globe. Because Earth Probes are smaller satellites with shorter development times, they have significant potential for providing high-priority precursor measurements to EOS, and they can advance the time in which some of the measurements critical to understanding global change could be made (see the SSB/CES report, *Strategy for Earth Explorers in Global Earth Sciences*, 1988).

Some measurements--for instance, biological processes and radiation studies related to cloud motion--require sampling at various times of day, and they cannot be made only from sun-synchronous polar-orbiting spacecraft such as those in the EOS program. To the extent that these measurements are critical to achieving the objectives of global change research, the Earth Probe line is intended to provide a flexible mechanism for such observations from more appropriate orbits. During the EOS era, Earth Probe missions will also be essential to complement the EOS measurements by flying instruments that may be incompatible with the design and orbit of the EOS platforms. It is expected that the Earth Probes will be augmented by foreign spacecraft, some of which could provide flight opportunities for U.S. instruments.

4. Does the proposed EOS Data and Information System (EOSDIS) represent the appropriate approach to support this long-term data collection and modeling effort?

The synthesis of diverse types of information from different sources is the preeminent challenge to global change research. EOSDIS is a pioneering effort in this regard, and the intended scope of the system exceeds that of any existing civilian data management system. Nonetheless, relevant experience for developing EOSDIS exists in pilot data programs in NASA's Earth Science and Applications Division and in the data programs of other disciplines and agencies.

In a project of this scope, there are inevitably divergent views on the proper balance between distributed and centralized responsibilities for data management. The appropriate balance can only be determined through experimentation and experience. Thus, EOSDIS should have a system architecture sufficiently flexible to accommodate changes as they become necessary and to implement them in an evolutionary manner. A distributed system should be used to take advantage of colocated scientific expertise and computational facilities. This basic requirement argues strongly against the development of a centralized system. Another reason that the system must be flexible is to make it possible to take advantage of inevitable advances in hardware and software capabilities, particularly in the area of high-performance computing.

NASA has placed an unprecedented priority on the development of the EOSDIS, both in terms of budget and schedule. The panel especially welcomes the agency's plan to spend a greater proportion of funds on the ground segments of EOS than on its space hardware. Even more important, perhaps, has been the integration of NASA's Science Advisory Panel for EOS Data and Information into the agency's planning process. To date, the Advisory Panel has successfully focused the concerns of the broader research community, and it has articulated the specific requirements of the scientific users in the context of the EOS mission and the USGCRP, most notably in its November 1989 report entitled *Initial Scientific Assessment of the EOS Data and Information System*. This report was founded upon the recommendations made in a series of NRC reports by the SSB Committee on Data Management and Computation (*Data Management and Computation--Volume 1: Issues and Recommendations*, 1982; *Issues and Recommendations Associated with Distributed Computation and Data Management Systems for the Space Sciences*, 1986; and *Selected Issues in Space Science Data Management and Computation*, 1988) and by the Committee on NASA Information Systems of the Board on Telecommunications Computer Applications (*Critical Issues in NASA Information Systems*, 1989). The Advisory Panel should continue to perform its function throughout the EOSDIS procurement cycle and beyond to ensure that all the major scientific requirements are effectively implemented.

The success of EOSDIS, like that of EOS, will be judged on scientific results rather than by how many bits can be processed for the fewest dollars. For this reason, EOSDIS is being planned to include data sets from a diverse array of space- and ground-based data collection sources. Consistent with the discussion earlier in this report, the process should begin as soon as possible, and other agencies--notably NOAA and USGS--have critical roles to play in this regard. That appears to be the plan.

Further, NASA intends to have EOSDIS operational so the scientific community can begin to use it before the first EOS platform is launched. A number of impediments to accessing the data, however, are limiting the effective scientific use of the various data sets for global change research. These impediments relate to certain data management policies and insufficient resources for managing currently available data.

First, to maximize the scientific usefulness of existing data, all researchers should have easy access to data obtained through EOS missions and to data archived in the EOSDIS from other sources at nominal cost, for example, the marginal costs of reproduction and transmittal. The EOS program is to be commended for adopting policies that foster open and easy access to EOSDIS. Unfortunately, current legislation intended to protect the commercialization of land remote sensing activities prevents the inclusion of important Landsat data in EOSDIS. U.S. Landsat and French SPOT data, which would facilitate global change research, are prohibitively expensive for the research community.

The panel believes it is in the interest of international research to make all environmental data readily available to the scientific community. Only in this way will we maximize the utility of the data and the payoff from our investment in acquiring it. Means should be found to assure that the research community has prompt access to these data at reasonable cost.

Second, rapid changes in technology and insufficient attention to maintenance of irreplaceable historical data sets currently in various archives threaten to limit their usefulness. For example, almost all the NOAA 1-km AVHRR data obtained prior to 1986 have essentially become inaccessible because they are stored in an outdated system. Early Landsat data and many foreign data sets from space- and ground-based observatories are at risk of being lost forever because their storage media are deteriorating. The success of global change research will depend in part on the availability of a long time-series of measurements. The existing archived data are a most important resource in this regard. Once lost, they cannot be replaced. The panel underscores the urgency of moving all relevant data to more secure and accessible storage media and incorporating them into the EOSDIS as soon as possible.

QUESTIONS OF SENATOR GORE AND THE ANSWERS

Question 1. As you aware, NASA has begun the selection process to determine which instruments with that capabilities will fly on the EOS platforms. Many of these instruments are upgrades of existing satellite sensors.

What are the critical technology issues affecting development of EOS? Has an adequate technology program been put into place to ensure successful instrumentation of EOS?

If the number and type of instruments for EOS were to be reduced, how would the scientific value of the program be diminished? Is there a prioritized list of instruments that would be eliminated if the EOS program budget is cut?

Answer 1 (a). Many of the instruments under consideration for flight on EOS platforms, or in the Earth Probe series, have a firm heritage in technologies previously demonstrated or currently in use. To achieve some of the important EOS measurement objectives, however, significant advancements in some of the technologies will be required. The question of whether the technology development program currently in place or envisioned will be sufficient to ensure successful achievement of all EOS instrumentation objectives is still under consideration.

(b). Each of the instruments that is being considered for the EOS mission, or for the Earth Probe series, has specific tasks and scientific objectives, both as an individual sensor and in a scientifically synergistic context with other sensors. To the extent that the number and types of instruments are reduced, the scientific value of the missions would certainly be diminished, and some of the stated goals of measuring global change would not be achieved. NASA's EOS Payload Advisory Panel is in the process of recommending priorities for the proposed EOS instruments. A scientifically rigorous review of any payload descoping would have to be carried out by NASA in configuration with the scientific community in the event of a budget cut.

Question 2. Mr. Tapley, your panel has addressed the question of whether the EOS platform should be outfitted with an array of instruments capabie of collecting data on various environmental parameters simultaneously. In fact, your report favors simultaneous measurements in "certain cases."

Can you elaborate on what these cases are? Also, what types of scientific measurements must be made simultaneously to ensure accurate data collection? How critical is simultaneity to developing a complete understanding of global change?

Answer 2. The preliminary report describes the circumstances under which simultaneous measurement of several parameters is technically and scientifically desirable. These include requirements for particular classes of instruments being flown together, e.g., imaging instruments, ranging instruments, and sounding instruments. The requirements for simultaneity are also drawn from consideration of the time variability of the phenomena under observation. The final report is likely to contain a consideration of the specific instruments that should be grouped to meet priority scientific objectives.

Senator GORE. All right, very good. We have a series of questions to go through and I will ask for the patience of our second panel, Dr. Fisk and Dr. Corell.

First of all, let us review the headlines of the week. The Tiros satellite study. Do you all have any thoughts on that, first of all, on the study itself and secondly, on the way in which it was interpreted by headline writers and lead paragraph writers?

This, of course, was the study of archive data from Tiros-N Weather Satellite, showing that temperatures in the troposphere from 1979 through 1988 could be more accurately measured by satellite than through the ground observations.

During the 10 year period studied, there were wide variations in the annual global average temperatures. The researchers concluded: First, the method of collecting the temperature they pioneered is superior to the ones used in the past; second, the variations were more extreme than they expected; and third, no inferences could be made pro or con as to a long-term global warming trend.

I read some headlines that said there is now evidence of no global warming. Dr. Eddy, could you respond to this or tell us what your thoughts are?

Dr. **Eddy**. I should like to respond to that, Senator. I think I have many of the same feelings as you. There are probably two important points here. Maybe I should take the negative one first, that we have to be very careful about headlines.

It seemed to me like a terribly important paper and a very interesting paper and it is always a little bit disappointing to see it get reduced to a few words that oversimplify the case.

I do not think it particularly significant that over the last 10 years you cannot see a significant increase measured by this method, assuming that the method is indeed measuring the surface temperature and not a combination of the atmosphere where there will be cooling as well. Even if that is the case, it does not lighten my concern in the slightest about the overall concern of global warming which to me seems imminent.

A more important point and the one I should make first is that this study brings home the point about what we are talking today, that space-born measurements provide a power that cannot be achieved in other ways. This may indeed demonstrate the initial feasibility of taking the temperature of the whole Earth, the parameter we would like most to know. Perhaps we can do it now from space.

I will make a bet with you that as we look further at those data and other people look at them, it will be refined some and there will be some changes, but it is a way of making the measurement.

I do not think I have to remind you of the fact that any other way of deriving this most important parameter is so unsatisfactory that we have to rely on an external monitoring system that can look at the Earth as a whole.

As a final point, I should like to remind you of Professor Helmut Landsberg who was a climatologist at the University of Maryland, a very distinguished man, who was associated with something called the "Landsberg Statistic."

It was a number whose value I think was equal to something times 10 to the minus sixth. It was a point he made in stressing that we do not even know how much rainfall the earth receives. The Landsberg Statistic is the fraction of the earth's surface that is covered by rain gauges: therefore, what we know about world rainfall is something at that level.

You could almost say the same thing about temperature, where space-born measurements promise a lot. So I took that paper as very good news. I took the headlines as what we have come to expect.

Senator **Gore**. Thank you. Dr. Baker.

Dr. **Baker**. I would just like to add to what Jack said. I think the very important point made there is that it is possible to use satellites to make measurements where we cannot do it on the ground. The relation to global change is that the models predict a variation in global temperature as CO_2 increases with bigger increases in the polar regions. Those are the areas that we find it most difficult and the most inaccessible to make measurements. Yet, with the satellites we can make both surface temperature and measurements throughout the atmosphere of temperatures. So, the paper shows the power of the global technique.

The second point is that I think it is just a fact that the warming signal is not yet out of the natural variability and noise in the climate system, and until the signal is larger than the noise it's always going to be possible to pick out a length of time over which the temperature will go up or down. The signal of warming is not yet there.

Senator GORE. Dr. Tapley, do you want to add anything?

Dr. TAPLEY. Yes. Just the other two points, that I think taking the case out of context and looking at where we are in observing the consequences of global change, I suspect that as we analyze more of the long-term data sets, we will see this sort of thing happening from time to time. I hope we can focus our debate on the results and/or the methods being used, rather than taking them out of context to obtain sensationalized interpretations.

I think there are two things we question in any of the current results: The technique used for analyzing the data and the sensors accuracy. One of the things that I think we must consider in the use of the historical data set is the accuracy with which the sensory bias and drifts have been calibrated and to be sure that they were calibrated in a way that will allow one to actually measure decadal type of trends, which is what we are trying to do in the global change initiative.

Senator GORE. Some of the ground temperature measurements showed no discernible trend during the 1980s, but nevertheless, showed the decade of the 1980s to be by far the warmest decade since measurements began. There are no satellite measurements of the kind collected by Tiros-N earlier than 1979 so it is impossible to measure the decade of the 1980s against earlier decades by this new technique, correct?

Dr. BAKER. [Nods affirmatively.]

Senator GORE. I remember last year there was a headline about temperatures in the continental United States collected over a hundred year period showing no warmings. For a few days afterward, many asked the question: Well, doesn't this show that there is no problem to worry about? Until the study was placed in context with the point that the continental United States makes up about two percent of the land surface, of the earth's complete surface, and one would not expect to see a global trend in the one degree range over 100 years in a given two percent slice of the earth's surface.

Similarly, a long term global trend would not necessarily be found at all in a given 10 year slice, and that's the essential point that I heard the authors of the study make in response to some of the headlines written about their study. Indeed, the head of their division sought me out with a copy of their original paper and a copy of the press advisories which they themselves put out in order to draw the sharp contrast between what they said and what was put out as a result. Indeed, Science magazine's own press advisory promoting the upcoming article put a statement in the lead paragraph to which the team of researchers took strong exception. But, that's normal and natural, and having been a journalist myself for seven years, I've certainly done the same thing, but it is important to put that study in an accurate context.

I also agree with the statements made by this panel that the technical proficiency with which these researchers use the Tiros-N data does demonstrate that it's a very promising technique. It reminds me a little of the kinds of questions doctors now confront when they use a nuclear magnetic resonance image when they are used to interpreting x-rays. The amount of data and the accuracy of the data are both greatly enhanced. Sometimes the questions posed by the wealth of new data challenge the doctors to go back to their old x-rays and use the experience base they have gained in interpreting that knowledge in order to make crucial decisions that they are not comfortable making on the basis of this new, sophisticated technique. But, it's a very promising technique. How high is the column of air measured by this technique? Do any of you know? You mentioned the averaging of tropospheric temperatures at different attitudes, Dr. Eddy.

Dr. EDDY. It is one of those questions that it is hard to answer, Senator. It's going to be weighted by the distribution of mass in the air column, so what you will measure is an average or an integral going from the surface on up, weighted according to how much the air is distributed.

Senator GORE. Fifty percent of the total weight is in the first three and a half miles.

Dr. EDDY. That's right. It will weigh chiefly the lower troposphere, but you're going to have an effect of the upper atmosphere, and I'm sorry that I don't know the exact way that is going to be resolved, but I'm sure there will be a subsequent study of that.

Senator GORE. All right. Now, in any event, this dialogue in the press and the miniature dialogue we have just had over the last few minutes, both illustrate the importance of collecting long term data sets over a period of years, and that is exactly what EOS and the larger Global Change Research Program is intended to do, is that correct?

Dr. BAKER. [Nods affirmatively.]

Dr. EDDY. Absolutely. If I may answer that, I think that is the highest calling of the program. It will be the greatest legacy of the program to the future. I like to think of 20 years from now when you or other senators are asking other scientists questions. If this program really works we should have a lot better answers based on that longer stream.

Senator GORE. All right. Very good. In your report, Dr. Eddy, you emphasize the fact that because the Global Change Research Program is implemented at the agency level, there will be a continuing need for interactive review by the research community. Are you satisfied with the manner in which the program has proceeded thus far? Has the Committee on Earth Sciences been, in your view, an effective planning mechanism for the Global Change Research Program?

Dr. EDDY. The answer, Senator, is yes. I think that what has been unique has been the real time interaction between the committee on earth science and the academy advisory. There have been some differences and we are still looking at different minor parts of the program, but the interaction has been real and active.

My only reservation in your question is the following. We are reaching the point when the program is developing so rapidly that the response, the normal response mechanisms of an academy committee, which I am convinced are necessary, are being taxed by this process and we may need to think of new ways within the National Academy and the National Research Council to make it a more interactive machine.

Senator **Gore**. So, as we move beyond the early planning stage to the stage where critical decisions have to be made about which instruments to put on which flights and which questions to be assigned which priority, the decisions may need to be made more swiftly.

Dr. **Eddy**. Yes.

Senator **Gore**. And a committee structure with no individual really in charge may be taxed more heavily than it has been up to now in the program, correct?

Dr. **Eddy**. That's correct. Our concern, I think, is that a value of the deliberation process is the time it takes to do it. There is an advantage in a slower review as you know, yet you have to make decisions very fast every day. We must find a way that still keeps that prudent, responsible control and yet can respond fast enough.

I think our concern, which I'm sure the CES also shares, is that this program be kept flexible, recognizing that the problems of today may not be the ones that loom three or four years from now. The last thing we want to do is to start off a giant kind of Soviet machine that keeps going in the same direction long beyond its time. It has to be something that can respond to new needs at the same time building the data base that future scientists will need.

But, yes, I think we do need to think of ways to insure that this level of advice is there and it's done on a workable basis.

Senator **Gore**. Dr. Baker, do you agree with the suggestion we have just heard, that the program may be reaching a new stage where faster decisions are needed and the committee process will be overly taxed or may be overly taxed during this new phase?

Dr. **Baker**. I am glad you asked me that question because I was going to respond.

Senator **Gore**. You were going to find a way to answer it anyway?

Dr. **Baker**. That's right.

Yes. I think the program is moving to the point where fast decisions must be and are being made, but no, I do not believe that's a committee activity. I don't think that a prudent manager of a space program would try to turn to an interagency committee to try to make a decision about which instrument would fly on a platform. Those are detailed technical questions that require expertise and fast decisions and have to be made in the context of an overall program. But they must be made by those people who are directly involved, that is the agency and the scientific community. I think the system we have for making those decisions is a good system. I think that overall, NASA, NOAA and the Department of Defense can make their decisions about instruments.

Where we have seen a very positive aspect is the CES providing a context and oversight for the program. I think the CES system has worked well, but as Jack Eddy has pointed out, the question of making a connection between the scientific research committee and the CES through the National Academy of Sciences is one that could be more responsive. I don't know the answer, but I think that connection is an important one.

One of the reasons that it has been interesting is that the CES has been a very active and effective committee of the Federal Coordinating Council on Science, Engineering and Technology. At the risk of offending my friends in the administration, that's not the usual case for such committees. Usually, they move slower than the academic community can respond. Here, we have a committee that is taking leadership and moving ahead. Now the academic community is trying to understand and work out how it can respond in a faster way, which I think is good for both sides.

Senator GORE. Did you have a view on that question, Dr. Tapley?

Dr. TAPLEY. I share Dr. Baker's view. I think that the charge for establishing the science requirements must lie in the role of the scientific community. The essential point in the overall process is that when the implementation by NASA goes forward, that there be a dialogue or a procedure for checking the response to the science requirements. I think that procedure is in place.

Senator GORE. Well, I wonder if it really is in place. The committee is in charge, is that correct, Dr. Baker? Who is in charge?

Dr. BAKER. It depends on what you mean by in charge. That would have to be defined.

Senator GORE. Well, then, let me define it for you. Which human being is ultimately responsible for the direction of the Global Change Research Program?

Dr. BAKER. Well, I think in the existing structure, and probably you would have to get the representatives from the administration to answer that, it is the President's science advisor. That is where the responsibility is located in the government.

Senator GORE. The Global Change Research Program?

Dr. BAKER. Right.

Senator GORE. Dr. Eddy.

Dr. EDDY. I think I agree. In fact, the major driving force now, if there is an executive force, is at a level below that: at the level of the Committee on Earth Sciences and a few key individuals in the agencies that are concerned.

Senator GORE. But if it is the President's science advisor, he has got a lot on his plate. We deal with him in this subcommittee on a whole range of issues. He cannot be the person responsible for day to day decision-making and management of the program. The big issues will ultimately work their way up to him if he is the person below the President in charge, but does there need to be somebody below him who is actually in charge of this program?

We will pursue this with the next panel and maybe it is more appropriate to do it there. I don't want to cause any undue discomfort to you all. If you wish to volunteer an opinion and blurt it out here, you can certainly do so.

Dr. TAPLEY. Well, considering the question in the context of the global change program, I think that with regard to the sensors flown in the Space environment, the agencies have a major role. However, the quantites that need to be measured, and the parameters that need to be measured, and the requirements for data input to the models are requirements that must be carefully specified by a broad community. However, the implementation issue of what needs to be flown to meet those requirements is best left to one or two agencies. The agency process for achieving consensus on these issues through the CES seems to be working.

Senator GORE. Yes. But if the technicians decide which instrument to fly, then that decision may not reflect a considered judgment on the best, cheapest, speediest way to get the information you are trying to collect. It's another reason why I interrupted Dr. Baker's statement unnecessarily to ask about the context of the global change program within which the satellite programs are pursued.

Let me give you an example. One of the priority questions which needs to be answered is, where are the clouds, what is the distribution of clouds on earth?

A decision to place several instruments on EOS to help us answer that question, might well be made by the person in charge of EOS, but if there is no single individual in charge of deciding how to answer the underlying question, where are the clouds, then the country as a whole may miss a cheaper, faster opportunity to answer that question in a completely different way.

We have taken a complete photograph of the earth's surface every two weeks for the last 18 years, just with one satellite system already in existence, and presumably if we could pull out the needles from those haystacks, we could answer the question, where are the clouds? It might be a cheaper way to do it, we might get the answer faster, and we might then conclude that we still should collect the data on EOS. I'm confident that we would continue with that plan.

But, if our objective is to answer that question as quickly and cheaply as possible, there might be a much better way to do it. If nobody is in charge of making that decision in the larger context of, what is the best way to answer the question, then we may miss some good opportunities. That's really, sort of what I'm getting at in that question.

Dr. BAKER. Let me try to speak directly to that question. You are talking about a scientific issue and trying to understand a scientific problem about how the earth works, and clouds are a key element. The interaction of clouds and radiation is a key element of understanding global, climate change. There is simply no question about that.

After the first global atmospheric research program experiment, which was in 1979, the scientific community, as represented by a number of leaders in understanding climate change, got together and said, there are some specific issues we have to understand if we are going to do climate. One is the role of clouds. We have to have long term satellite measurements of clouds and we have to have a research program to understand the processes. They established a program, the International Satellite Cloud Climatology Program which is now operating very successfully, in fact, provides regular maps of clouds. The program involves a very large number of people around the world trying to understand the role of clouds in climate.

Senator GORE. Right.

Dr. BAKER. Now, NASA, NOAA and parts of the Landsat system have responded, in fact, to that program. The EOS system is designed to collect enough data so that we can understand the physics of clouds and how they work by making simultaneous measurements of the relevant parameters. Today, using AVHRR and other operational satellites, we are able to get initial maps, and as you say, we have these for study now. So, this is an area where the scientific community and the agencies have responded to an organized program. There is somebody in charge of the program. There is a project office, there is an international context, and so on, so that specific issue is being addressed.

Senator GORE. Where is the project office?

Dr. BAKER. The project office, I think, is in Geneva. Is that right?

Dr. TILFORD. Well, actually it's headed up by Bob Schiffer of NASA who works part-time on it.

Senator GORE. Okay.

Dr. BAKER. But one of the questions you could ask is even if the scientific community had identified that problem, what if there are gaps that they didn't identify that are important. Who is looking at that? That is a strategy question which I think the scientific community continually wrestles with. It is why we have programs like the World Climate Research Program where you look for gaps. The new program, the International Geosphere/Biosphere Program, came up precisely because there was a feeling in the biological community that the biological and chemical aspects of climate were not being identified by the World Climate Research Program. So that's a bubbling up from below if you want. It doesn't answer the question of who's in charge, but it tells you a little bit how the strategy works.

Senator GORE. Okay. Let me pause at this point because we have a vote on the floor and with apologies, I am going to have to briefly recess the hearing. I estimate it will be about eight to 10 minutes to get over and vote and come back, so I apologize, but it is necessary that we have a short recess.

[Recess.]

Senator GORE. The Committee will come to order. On funding, it is my understanding that yesterday the House Budget Committee recommended an overall spending level for NASA in Fiscal Year 1991 of approximately $1 billion below the president's request.

How will the Global Change Research Program be affected if the Earth Observing System is delayed or its scope cut back in any significant way?

Dr. BAKER. Well, the first question is, just because NASA's budget is cut $1 billion, doesn't mean the Earth Observing System is cut.

Senator GORE. Right.

Dr. BAKER. Probably is cut, that is what you are saying?

Senator GORE. I hope not, I hope not. But if that budget allocation remains in effect and that may not remain in effect, I hope it does not. But if it does, it at least poses the possibility of a cutback and I hope that does not come to pass.

But I want to build a record here by asking the question. If the Earth Observing System was delayed or its scope cut back significantly, how would that affect the Global Change Research Program?

Dr. **Eddy**. I think, Senator, it is going to have a serious effect on the timing of the overall program. It will have a very serious effect on the international aspects of the program, which are, as you know, crucial.

To defer this essential element, for who knows how long, even a year, I think is a very costly step. As I was riding over in the taxi, I was wondering what if there were no Earth Observing System in the Global Change Program and that is a thought we do not like to think.

So I do not think one can emphasize the cost to the impetus of the program, the cost to the international involvements which rely on action on the part of the United States as a leader. I think it would be a serious blow.

Senator **Gore**. Anybody else want to address that briefly?

Dr. **Baker**. Let me just say that the cuts in the space program almost always translate to delays, so if in fact the program were cut, then you would have to look at delays in some components and there would then be a question of trying to look at the highest priority parts and to see how that could be put together.

But with a large, complex program, I think it is not possible to say immediately what one could do. I think there are—it might be possible to do parts of the program. On the other hand, remember we are going two things with the Earth Observing System.

We are providing continuity of long-term data and we are providing a way to get measurements that we cannot get in any other way, and if we delay that, it takes us that much longer to get the understanding.

Senator **Gore**. You pose the question, Dr. Baker, about choosing between answering a particular question by means of EOS or answering it with near-term satellite launches.

What near-term options exist to find answers to pressing questions? Would, for example, a more comprehensive Earth Probes program or an effort to promote the examination of other data be a good way to answer some of these questions quicker and more cheaply?

Dr. **Baker**. I do not see these proposals as something that one does instead of EOS. I think right now we have what I would call a comprehensive Earth Probe System. In fact, one of the things that our committee did was to look at the proposals for the Earth probes to see if we could see if there were gaps in those smaller satellites that could fly to give us data that we need between now and the time EOS flies and after EOS, because remember, they have different orbits.

And it was our view that on the books we saw most of, if not all, of the kind of measurements that needed to be made. Now not all of those Earth Probe systems are in the budget right now, and some of them are more firm than others.

But we feel that there is a comprehensive Earth Probes program. We also feel that if the EOSDIS program goes ahead as planned, it will be providing the access to near-term data that we are looking for.

But I should say, we see this combination of Earth Probes and EOS as something that needs to go together. It provides the data we need and we would not like to see either one compromised for the sake of the other.

Senator **Gore**. It is fair to say that science builds on itself and questions get better as more information is gathered. Therefore, if you agree with that premise, data collected by near-term Earth Probes could improve greatly the usefulness of the data collection process carried out in EOS.

In other words, if we refine the questions and develop a better understanding of exactly what we are looking for, how to look for it, where to look for it, then the capacity built into EOS could be far more productive as a result.

Is that a fair statement?

Dr. **Tapley**. I think it is, Senator. There is not only the critical process of understanding which questions should be asked, but the point we mentioned earlier, that the initial measurements for some of the sensors that will fly on EOS can be made, and some of the existing historical time series can be continued by the Earth Probes.

The important point we want to remember is that EOS, in order to satisfy the complete requirements of Global Change, requires not only measuring and observing the change, but the predicting of its future evolution, and from that point of view, we have a very big job in bringing adequate models and data together to be able to understand how to put the data into models to be able to make the predictions. The data sets we can collect in the time period prior to EOS launch, along with the historical data set, could play a major role in feeding the earlier models and helping to be ready to actually ingest the EOS data when it is eventually available.

Senator **Gore**. All right, let me ask some—so to summarize that set of questions, none of you see an effort to get priority answers more quickly through near-term Earth Probes, as in any way inconsistent with the EOS program?

Let me shift to data management. Dr. Baker, your report urges that the process of developing the EOS Data Information System should begin as soon as possible. I agree absolutely, and am pleased that NASA intends to make this a priority.

In your view, Dr. Baker, will the Earth Observing System Data Information System, I will refer to it as EOSDIS, will it put the data management aspect of NASA's effort on an equal footing with the measurement devices and data collection part of the program?

Is it too early to answer that question?

Dr. **Baker**. No, I do not think it is, and in fact, it is a very important question, one that I think the scientific community felt very strongly about.

The funding profile for EOS as a program in general has something like 60 percent for ground and data management activities and 40 percent for space hardware which is the reverse of the normal kinds of funding for a NASA program, and I think this is evidence of NASA's commitment to a proper data system.

I think we have seen a complete turnaround in the last 10 to 15 years in NASA in terms of the recognition of the importance of data. The very strong emphasis on the data and information system for EOS and a recognition that if that does not work, the program does not work, I think, permeates the program and is exactly what the scientific community had been looking for.

Senator GORE. What is the data information system going to look like?

Dr. BAKER. Well, there are many answers to that question ranging all the way from the details of the computer architecture, to the way in which the data systems work, and then up in the sky, the data transmission satellites as well as the satellites that carry the sensors.

So what you are looking at is a very complex system, but in brief, you could say a distributed system, not centralized, that provides easy access to a wide variety of users.

Senator GORE. Let us take for granted the satellite is in orbit. They are sending the information down to the Earth's surface. Where do they send it?

Dr. BAKER. They send their information primarily to a data relay satellite, which then transmits the data down to the surface.

Senator GORE. To where?

Dr. BAKER. To receiving stations which are primarily in the U.S., but I think there are receiving stations around the world. Let me just check.

Dr. TILFORD. There are two types of data that are sent down, one through TDRSS, at the White Sands Missile Range where it is then distributed to distributed data sets. There is also direct broadcast——

Senator GORE. Hold up just a second, we are going to drive our reporter crazy here. If you could come up to the table next to Dr. Eddy and identify yourself. Dr. Shelby Tilford of NASA.

Dr. TILFORD. The primary data downlink will be through TDRSS to the White Sands Missile Range and then the data will be relayed to the various distributed data centers, probably 7 of them.

At the same time we will have a direct downlink capability such that current or improved meteorological receiving stations can receive parts of the data.

Senator GORE. Say that last part again.

Dr. TILFORD. A direct broadcast downlink, such that current or enhanced meteorological receiving stations can receive similar kinds of data for oceanography modus, those kinds of data that may be needed for operational purposes in regional or local areas.

So we will be doing both. The primary data stream will come to White Sands, but simultaneously throughout the world, there will be a direct downlink system.

Senator GORE. What will that data stream to White Sands be like? How many bits per second?

Dr. TILFORD. It will be a maximum of 300 megabits per second, which is one TDRSS channel, dedicated.

Senator GORE. 300 megabits per second.

Dr. TILFORD. Maximum. An average data rate, I believe, is 100 megabits per second.

Senator GORE. How? What part of the spectrum does it come down at?

Dr. TILFORD. You are talking to someone who does not really know what particular wavelength we are talking about, but these are the normal TDRSS channels. Do we have any Code T people in the audience? I will get that information for you.

Senator Gore. Just supply it for the record, that will be fine.

[The following information was subsequently received for the record:]

The term "broadcast satellite" refers to a satellite which broadcasts program material to the general public in a form which requires a receiver such as a television or radio for proper reception. They broadcast in a band between 12.2 and 12.7 gigahertz (Ghz) in North and South America, and between 11.7 and 12.2 Ghz in the rest of the world. By contrast, NASA and communications satellites transmit data streams in a different portion of the spectrum (1.7 to 1.8 Ghz). These satellites are referred to as "Multidistribution satellites in the broadcast mode."

NASA uses its Tracking and Data Relay Satellite System (TDRSS) to beam information back to Earth. Other spacecraft send their information to the TDRSS, which then relays the data stream to scientists and others on the ground. TDRSS uses a variety of frequencies for these relays, all of which are outside the broadcast spectrum.

Dr. Tilford. The direct broadcast will probably be X band or S band. I believe the TDRSS main channel will be KEO, but I will get you the correct answer.

Senator Gore. Fine. Then how is it distributed from White Sands to the 7 centers?

Dr. Tilford. Depending on which particular data stream goes which place. I mean, what we have here, eventually from the EOS-A and EOS-B platforms will be data from up to 28 instruments.

Part of that is imaging data so it is very high data rate. Part of it is from what we call low data rate sensors and those, all the low data rate sensors will be distributed through relay satellites back to the particular distributed data center that will be handling the data.

We are still looking at the most economical way to transfer the high data rate. It probably will be by relay satellite, but we are also looking at the cost effectiveness of potential ground circuits in terms of looking at optical networks.

That is something I think we have to do in terms of the quality and quantity of the data, and that study is underway right now.

Senator Gore. So you are not sure yet how it is going to be relayed from the initial downlink to the distributed centers?

Dr. Tilford. Well, there are two ways of doing that with current technology. One is back through a relay data satellite and the other one is through an optical fiber network——

Senator Gore. I understand, but you have not made that choice yet.

Dr. Tilford. That is part of the recommendations I believe that will be coming forth as the Phase B studies that are going on for EOSDIS right now.

Senator Gore. What kind of computers, do you have any idea?

Dr. Tilford. We have a whole spectrum of computers that we are considering in terms of what is required for EOSDIS. These involve, as a follow-on to the example that we used for the upper atmospheric research satellite, the size of the computer is essentially size based on the data rate that will be coming down for a particular instrument. So you may have a very small computer which is capable of looking at data from one of the CDHFs at a PI's individual terminal. We expect that these will be provided to all PIs through supercomputers which will be handled in terms of modeling some of the data for the global climate and global change models.

Then we will have intermediate size computers at each of the racks or the place where we are doing the data reduction. I will be happy to provide you, once the Phase B studies are completed, the results of those studies.

Senator **Gore**. Now, in terms of dealing with the information that is distributed, how important is data processing cost?

Dr. **Tilford**. For this particular program data processing costs are a large percentage of the program.

Senator **Gore**. So if you found a way to cut your data processing costs, that would be a significant factor in your design of the program?

Dr. **Tilford**. Provided it maintains the quality of the data, that is certainly true. The main thing, and what we have found in the past, that we would like to reduce most of the data in semi-real time, such that we can get the data out to the investigators, in a few days at most.

None of the systems that exist today, especially for imaging data, have had that capability. This is one of the things and one of the reasons we have tried to look at a new approach to getting data down and getting it reduced in essentially real time. We think this is a critical element of the program, and this is one that both the Academy and all of their advisory committees have recommended that we implement.

Senator **Gore**. Now the EOSDIS system then consists of the instruments collecting the data and beaming it down. It consists of the initial downlink and then the system for distributing it to the centers where it will be analyzed, correct?

Dr. **Tilford**. You got it right to the last point.

Senator **Gore**. Okay.

Dr. **Tilford**. There is an interim step in there, that we will distribute it from the central White Sands Region. Then to 7 different places where the data will be reduced into geophysical parameters.

After it is reduced into geophysical parameters it will be archived and then the archived data will be made available to the scientific community as a whole.

Senator **Gore**. How?

Dr. **Tilford**. Through essentially a catalog, browse, dial up, get your information over the wire if the data rate is not too high. We are still looking at the optimum method in terms of cost for relaying imaging data.

Senator **Gore**. Wait a minute, that is an important point: if the data rate is not too high. Now what does that mean? How high does it have to be?

Dr. **Tilford**. I can give you those details, but if we wanted 4 or 5 Harris images, it would—on a 9600 baud line, it would probably take several months to get that data. That is not an efficient way of doing business.

Senator **Gore**. Which means as a practical matter, we will be right up against the same situation we have now.

Dr. **Tilford**. No——

Senator **Gore**. 95 percent of the data collected is not looked at.

Dr. **Tilford**. I am sorry, I believe you misinterpreted my answer.

Senator GORE. No, no, if we went that direction.

Dr. TILFORD. If we went that direction——

Senator GORE. I understand that you have fully anticipated this problem, but I want to get it on the record. One of your bottlenecks then is the rate with which data can be transmitted from the archive to the researchers, correct?

Dr. TILFORD. For imaging data, that is correct, that will not be a problem for any of the other data.

Senator GORE. Yes, but the volume of data is so much, is so great that for virtually all of it, you have to have visualization in order to understand it.

Dr. TILFORD. You have to have visualization, but it is not imaging data. There is a very important difference between the two.

Senator GORE. But is not the data rate requirement for visualization very high as well, for most visualization?

Dr. TILFORD. No, it is high, but it is not very high. The point is that, for instance, we could reduce most of the atmospheric temperature sounding data and it could be handled on normal channels if we reduced it in real time.

That would not require anything beyond what exists today in terms of the networks that are in place. If you wanted to do the same thing for overlaying many images of the same kind and many different spectral bands, it would require something greater than what we have today.

Senator GORE. Now you said in response to the question on what kinds of computers—I am not asking for brand names or anything like that, but Dr. Baker referred to architectures.

Is there any particular approach that is better than any other for this kind of task?

Dr. TILFORD. There are approaches that are better than others. What we are trying to do is get the approach correct. We, as you know, will be issuing an RFP for the EOSDIS late this year or early next year.

I want to be very careful that I do not say anything that gives any particular vendor the impression that I think his system is better or worse than any others. I certainly believe that is true, but at this particular time, I would rather go through the normal procurement process.

Senator GORE. All right. Anybody else have a view on that? Is it fair to say that a parallel approach is probably better suited to sifting through mountains of data to locate variables that give a clue, that tag the significance of the needle in the haystack?

Is it fair to say that parallelism is an inherently better suited approach to that particular task?

Dr. TAPLEY. I think there are some aspects in which parallel processing brings a very unique capability into play. I think that is going to be one of the architectural developments that will come into play during the lifetime of EOS, while the EOSDIS is being put into place. Under the current plans, one of the thrusts of the EOSDIS design is to evaluate the hardware along with the computing requirements, to be sure that the correct hardware is in place.

Senator GORE. Is it fair to say that no one has ever dealt with the volume of data that will be associated with this program?

Dr. TAPLEY. That is certainly correct.

Senator **Gore**. Is it fair to say that no program in the history of our civilization has ever even come close to dealing with the volume of data that will be associated with this program?

Dr. **Tapley**. That is true.

Senator **Gore**. Is it fair to say there is an order of magnitude difference? No, I will not pursue it, but in fact, that is the case, if I am not mistaken, it is an order of magnitude.

Dr. **Tapley**. The task involves not only the collection and archiving of the initial data itself, but the processing and archiving of the data to meet the Global Change objectives will create extensive additional data sets. The high level products that are created from the original data have a compounding effect, so the overall data gathering and storage requirements are unique in the annals of scientific computing.

Senator **Gore**. What percentage of the total cost in EOS is associated with data management?

Dr. **Tilford**. Data management and science, which I am putting several things together here, data management, science and operation is a number that was quoted by Dr. Baker earlier. In the run out of the program it is 60 percent.

Senator **Gore**. 60 percent of the total cost. What percentage of that number would be made up of data processing costs?

Dr. **Tilford**. In terms of that 60 percent, and this is an estimate, and I will get you the correct number, but I would say that probably 60 percent of that 60 percent is associated with the data and information system.

Now that is a little bit more than you ask, but I am trying to put it in perspective.

Senator **Gore**. No, that is very helpful. Anybody have a different view?

Dr. **Tapley**. That is an impression that we believe is correct.

Senator **Gore**. Are any technological advances necessary to ensure the success of EOSDIS?

Dr. **Tilford**. I would have to say that I do not think that any technological advances are required to ensure the success. I think a number of technological advances would sure make our job a heck of a lot easier, especially in terms of the archival and storage techniques and retrievability.

Some of the things that have come on-line in the last 2 years make our job much easier than it would have been 3 years ago. It was impossible 6 years ago.

Senator **Gore**. I do not want to mix apples and oranges in this hearing, but we got into a situation with the supercollider and we are still in it to some degree, where people came in after the program was started and said, hey, there has been a new technological advance that is not built into the design of this, and we can save money if we go back to square one and do it differently.

I am certainly not endorsing that view in using it as a preface for my question, but it is fair to assume that between now and the middle of the decade, there will be fairly dramatic advances in computer technology.

What provision is being made in the design of EOSDIS to take advantage of these new developments as they occur, without building exit barriers that cost us a great deal if we want to shift gears to integrate a new advance in data management technology, 1 year, 2 years, 3 years, 4 years from now?

Dr. TILFORD. What we have asked in terms of the Phase B studies is to look into the evolutionary approach to the data and information system. In other words, we do believe there will be major technology improvements in the next few years.

What we have budgeted for based upon the historical obsolescence of both hardware and software techniques is that each 5 years the system will be upgraded such that over the total 20 year lifetime of the EOS program, we essentially will have replaced the total computing system 4 times.

Senator GORE. Anybody else have a view? Dr. Tapley.

Dr. TAPLEY. In the dialog between the outside communities and the project, this has been expressed as a major concern. I think the steps that they are taking to ensure that one standardizes the software languages will ease one of the bigger problems of translating software from one system to other. Standardized software and standardized interfaces will ensure that if you replace a particular computer with a more powerful computer, you are not out of business.

And I think the initial approach shows a very favorable trend. We will have to see what occurs in additional developments.

Senator GORE. Now I assume that in preparation for this hearing some of the witnesses at least anticipated a question about how EOSDIS is going to make use of existing data bases.

I have been posing that question, and I am happy that people are addressing it and I do think it is an important question, but I am still not sure what the answer is in the design of the program.

The program as described, EOSDIS, will have data collected from space, it is sent down, it is distributed, it is analyzed. Where is the input for all the data that is already collected?

How does that get into the system?

Dr. TILFORD. I may be able to give you a few examples of what we are doing. The data you talked about earlier this afternoon are an example of going back looking at satellite data, in an attempt to reanalyze it.

We have recently negotiated—and it is the same thing with the coastal zone color data, we have been through that, we now have that archived and we are making it available in real time to the community.

We have negotiated with NOAA to go back and look at all the TIROS sounding data, both from the infrared and microwave. We will re-reduce that, with an approved algorithms and make that available to the scientific community.

We have negotiated with NOAA for all the low resolution AVHRR data.

Senator GORE. Is that part of EOSDIS?

Dr. TILFORD. We are using this as some of the things to get ready for EOSDIS when it is in its full up operational mode. We think, utilizing the data sets that now exist, learning how to reduce them and how the scientific community can use these, are an important predecessor before we get to, when we are flying EOS.

So in addition to that, we are going to provide all the geostationary data. We will re-archive this on current media, probably optical disk and again, make that data available as part of the early EOSDIS.

So all the long-term data sets that we have access to or can get access to, with the potential exception of Landsat, which is tied up in a commercial issue which perhaps you should talk about some other time——

Senator GORE. I have been into that.

Dr. TILFORD. We are trying to reduce all these data and make them available to the scientific community.

Senator GORE. Okay, I will explore that in the next panel. Dr. Tilford, if you could remain for the next panel, we will explore that.

I am interested, if the members of this panel have anything to add to that particular question, namely, how do we get existing data built into the EOSDIS system?

We just talked about Landsat as an example. There are many, many examples.

Dr. TAPLEY. Many of the existing data sets are archived at regional archives now, and in some of the proposed structures these archives are nodal points in EOSDIS. For instance, the ocean data would be distributed through the National Ocean Data System at JPL, the data related to the land-surface issues that Dr. Tilford mentioned is located at the Goddard Space Flight Center, and I think some of these existing data sets could conceivably be a part of the initial EOSDIS as it is implemented. Landsat data is the big unresolved issue.

Senator GORE. Anybody else on that question? Why is the Department of Energy not a part of the information system?

Dr. TILFORD. The data holdings for the Department of Energy are for the most part with respect to geophysical parameters are primarily related to CO_2. All the data sets for CO_2 could be included very easily in terms of the kinds of things we are talking about——

Senator GORE. I am talking about in the opposite direction. Why are you not distributing the data to DOE, climate modelers, for example?

Dr. TILFORD. Our objective is to distribute the data to every modeler throughout the world. I mean, we do not mean to have any exceptions in terms of EOSDIS. The data policy——

Senator GORE. All of your, well, most of your 7 centers are NASA facilities——

Dr. TILFORD. Several of them are NASA facilities.

Senator GORE. 5 to be exact, 5 of the 7.

Dr. TILFORD. Yes, but this has——

Senator GORE. One is NSF and the other is——

Dr. TILFORD. One of them is the University of Colorado, NOAA and so on.

Senator GORE. Right.

Dr. TILFORD. The primary computing capability in the Department of Energy is in the large computers for modeling purposes. They have not been one of the principal players in archiving geophysical parameters in the past.

What we have tried to do is work with those institutions, either NOAA or USGS or NASA or the university communities that have had significant experience and have a cadre of individuals who not only know what the data is but how to use it, in order that we maximize, we believe, the ability to reduce and analyze the data in the future.

Senator **Gore**. All right. I will pursue that, and I take it, you have not locked in these decisions at this point, have you?

Dr. **Tilford**. There are a number of recommendations, before locking in any decisions we would like to have the results of the Phase B studies and then the subsequent comments on the RFP by university, industry and commercial companies.

Senator **Gore**. When will a final selection on the EOS archives be made?

Dr. **Tilford**. We expect that the final selection will be made in the summer to fall of 1991.

Senator **Gore**. 1991?

Dr. **Tilford**. That gives us time to prepare the RFP, have it commented on by the users including the scientists within EOS, university scientists outside of EOS, industry, et cetera. The final RFP will be released, hopefully in December or January—December of this year or January 1991, three months to reply and then an evaluation period.

Senator **Gore**. I would like you to provide for the record the list of the candidate sites and how they were selected as candidates and the list of criteria that you will use in making the final selection. Is that all right? Can you do that?

Dr. **Tilford**. We will do our best.

[The following information was subsequently received for the record:]

Seven centers, designated as Distributed Active Archive Centers (DAACs), have been selected to process, store, and distribute data from the EOS mission and from other Earth science spacecraft. These centers were selected based on three primary criteria designed to improve the function of the system:

(a) science expertise in the use of the data being archived

(b) institutional long-term commitment to support and maintain the DAAC function for at least 20 years

(c) existing infrastructure to build from (e.g., existing data system capabilities)

A team of data and information system experts visited each of the interested sites to examine the facilities being offered, the personnel commitment, and the level of institutional support for the function.

The seven DAACs are located at the following institutions:

NASA/Goddard Space Flight Center (Maryland).
NASA/Langley Research Center (Virginia).
NASA/Marshall Space Flight Center (Alabama).
USGS/EROS Data Center (South Dakota).
University of Alaska at Fairbanks.—Alaska Synthetic Aperture Radar (SAR) Facility (ASF).
California Institute of Technology.—NASA/Jet Propulsion Laboratory (JPL).
University of Colorado.—National Snow and Ice Data Center (NSIDC).

In addition, affiliated active archive sites are anticipated for a variety of locations around the country to provide additional data processing and applications. One of these would be the Consortium for International Earth Science Information Networks (CIESIN) in Michigan.

Senator **Gore**. All right. Now before we move to the next panel, let me say that the studies we have heard about from this panel assert that substantially larger research communities will be needed in various fields of earth sciences, such as global ecology and hydrology, in order to carry out this program. Is that fair to say?

Dr. **Eddy**. Yes.

Senator **Gore**. What can be done to ensure that the necessary academic development occurs?

Dr. **Eddy**. I think, Senator, that an essential part is that the U.S. Global Change Research Program include incentives to bring people into these programs. There are early initiatives there now, but we are going to have to make sure that they continue.

It is a real problem in the case of global ecology, or as you mentioned, hydrology, where we are chiefly restricted by the lack of people who have taken the global view. It almost requires initiating a new science and bringing new people into it.

I think by the way that is one reason why the long lead times on some of the data gathering programs do not alarm us in science quite that much. We are going to need to get the army together to use these data. We need to recruit and train that army.

Senator **Gore**. Yes. Is it possible that a shortage of manpower will substantially hinder progress in the Global Change Research Program?

Dr. **Eddy**. It is my view that it will not, that that manpower and womanpower pool will develop. There are problems that need to be attacked now and people working on them. We must always remember, Senator, that the effort is an international one, where we have strong support and strong alliance through the International Geosphere-Biosphere Program and the World Climate Research Program, to help meet these manpower needs.

Dr. **Tilford**. Could I comment? This is one of the issues that has been addressed by the Committee on Earth Sciences, and I believe you will see educational and training initiatives both from NSF, the Department of Energy and NASA.

We would like very much to coordinate these over the next few years. We are concerned from the point of view of making sure that we have the right people in this timeframe as well as just the number of people.

Senator **Gore**. Let me say that I am a little concerned, not by the testimony, but by how few people have really focused on the size and importance of this Mission to Planet Earth. EOS and the rest of the program represent the biggest international research program ever attempted by far and the most expensive.

We are talking about a program that could cost $17 billion over the 10 years, which is twice the price tag for the SSC, 8 times the cost of the space telescope. Just for Fiscal Year 1991, NASA is proposing a $260 million Mission to Planet Earth, more than the total cost of some satellite programs.

I am an enthusiastic backer in every way. I have urged NASA to do this, but very few people are focusing on it, and I do think that we need to look at it in great depth as well as build support for it.

I think it is our top priority in space, and I am grateful to those of you on this panel who have come here today.

We have some other questions for the record, but because of time we are going to have to move on. Before we move to the next panel, do any of the three of you wish to add anything to what has been said? [No response.]

Well, we will be in continuing dialogue with you on these subjects and really do appreciate your presence here today, thank you very much.

Dr. Tapley. We appreciate being here, Senator.

Senator Gore. I would like to ask Dr. Lennard Fisk, Associate Administrator for the Office of Space Flight at NASA to come forward, and Dr. Robert Corell, Assistant Director of the Office of Geosciences with the National Science Foundation to come forward, and Dr. Tilford, if you could stay with us up here.

I want to welcome all of you to this second and final panel of the day. Without objection, your prepared statements will be included in full in the record, and I will invite you to proceed with a summary.

Dr. Fisk, if you would, please go first.

STATEMENT OF DR. LENNARD A. FISK, ASSOCIATE ADMINISTRATOR, OFFICE OF SPACE FLIGHT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. Fisk. Okay, Senator. Just in case you are concerned, I am the person in charge of Mission to Planet Earth.

Senator Gore. Are you in charge of the Global Change Program?

Dr. Fisk. I am in charge of 60 percent of it because Mission to Planet Earth is the central component of that.

Senator Gore. Who is in charge of the other 40 percent?

Dr. Fisk. Dr. Corell gets probably 20 to 25 percent, and the other is in NOAA, a similar amount, and then there are smaller other agencies.

Senator Gore. Who is in charge of integrating the total?

Dr. Fisk. My prepared statement is going to be offered here in a bit.

As you know, the role of the CES has been to make a clear definition of what the agency roles are in this program. I think we have that, and we each have a charge, then, to fulfill those requirements. The requirements are set not only by the CES itself but by the many, many, many scientists who are involved in this program.

Senator Gore. Okay, I do not want to throw you off, Dr. Fisk. You go ahead with your statement. I think that the record should reflect that the answer to that question is that the committee is in charge and no single individual is in charge. There are good things and bad things about that which we will have a chance to explore.

Dr. Fisk. Great.

A lot of things have been said about Mission to Planet Earth, and I do not want to spend a lot of time repeating them. Let me just tell you a bit about how I see this program.

We, of course, have had a lot of help in developing it. There have been more than 1,000 scientists who have participated. We have had academy reviews about which you have just heard. We have chartered our own reviews of this. The interdisciplinary teams, for example, who are the people who use the data, are in constant review of this program, and, of course, we welcome that because the idea is very much to do it correctly.

Let me just briefly remind you about the components and how I see them fitting together. We will launch some 19 earth science missions between now and when the first EOS platform flies. In addition to that, we have access to data from seven international missions, and we have access to data from the meteorological satellites that routinely fly.

There is, I believe—and Dr. Baker referred to this—a consensus that these missions will provide all of the observations on global change issues that can reasonably be made prior to the launch of the OS.

There is also, I believe, a consensus that these near term missions will not provide the definitive information on how the earth will respond to continued human intervention. To do that, we need to understand the coupling and the feedback mechanisms which control the earth as a system. For that, you need the comprehensive long-term observations that only the EOS platforms can provide.

I believe there is a further consensus, which again Dr. Baker referred to, that the first EOS platform which is devoted to measuring the surface of the earth and the atmospheric corrections which are needed to make those measurements needs to be a large Titan IV class platform. It is a scientifically compelling argument based on a need for simultaneous observations.

The argument for the second platform which is devoted to measurements of the chemistry of the upper atmosphere, the ocean circulation and geodynamics is that for that to be large it is not a scientifically compelling argument; however, it may be the most practical approach. It appears that the most cost effective means of executing this program is to launch a regular series of similar size large platforms.

There is another issue which I think is important. There is currently no proven launch capability out of the West Coast from where you launch polar satellites for launching moderate sized platforms. As Dr. Baker referred, we have all ruled out executing EOS on a series of small satellites.

Mission to Planet Earth also includes, of course, earth probes which are essential to the success of the program. They provide near-term measurements and have been counted in that 19 to which I referred, and, perhaps equally important, they provide measurements from orbits other than polar orbit which are essential to understanding the earth.

As you pointed out, perhaps the most important aspect of EOS is the data and information system on which we are placing unprecedented priority both in terms of budget and schedule. It is our determination to use Mission to Planet Earth to cure the past sins of data and to improve the access and utility of existing data. There are many of these efforts under way today, some of which Dr. Tilford referred to.

We are determined to bring EOSDIS on line early in the 1993-94 timeframe. That is well in advance of the EOS launch. This will facilitate the analysis and distribution of data from existing and upcoming missions and, perhaps equally important, it will get us ready for the data from EOS by practicing with this near-term data.

We recognize also that the results do not come from data systems; they come from scientists, and we are funding an unprecedented amount of basic earth science research in this program through our 28 interdisciplinary teams.

Finally, as was mentioned just a moment ago, we are concerned about education. We have included graduate fellowships in this program to help ensure the next generation of earth scientists.

If there is something else we should be doing here for which there is a consensus among qualified scientists of its importance, we will be happy to try to accommodate it because it is my clear determination that we are going to do this program correctly.

There is probably no more important science project that we will pursue. We are attempting here to provide information that will allow us to protect the future habitability of the plant, and we have to be sure that we are going to succeed.

Thank you.

[The statement and questions and answers follow:]

Statement of
Dr. Lennard A. Fisk
Associate Administrator for
Space Science and Applications

National Aeronautics and Space Administration

Mr. Chairman and Members of the Subcommittee:

I am very pleased to have the opportunity to appear before the subcommittee to discuss NASA's plans for a Mission to Planet Earth.

Mr. Chairman, we are at a unique point in human history. We know we are affecting the Earth's global environment, yet the outcome of these effects on the world are unknown. Some of these activities are dramatic. We burn the world's forests at the equivalent rate of one state of Tennessee per year. We load the Earth's atmosphere with carbon in the form of carbon dioxide, a known greenhouse gas, at the rate of five billion metric tons per year.

The planet we are affecting is also the most complicated in the solar system. It is the only one with oceans and life; and the interactions among the oceans and life, as well as the atmosphere, the land surface, and the ice, produce a very complicated set of mechanisms which control how the Earth behaves. And we are remarkably ignorant of how it all works.

In essence, then, we are conducting a gigantic global experiment, the outcome of which is unknown. And since nature tends not always to work in our favor, we should be concerned that the outcome will not be favorable. Clearly, we cannot let this ignorance persist - we need to understand the Earth in a global sense, and we need to do so immediately. We need to understand how it works so that we can better assess how to effectively protect the future of the planet.

We need to recognize that because of these large uncertainties, it is difficult to know what actions should be taken. This is particularly true considering the significant economic and societal input associated with some suggested actions. A reduction in fossil fuel consumption, for example, by as little as 20% would have a dramatic impact on the world's economy. Clearly, we need an accurate scientific road map for how the Earth might respond to human activities so that we can chart a course which both protects our environment and our economy.

The President has proposed a comprehensive global change research program, the U.S. Global Change Research Program, to reduce the scientific uncertainties of pending global change. NASA's part of this program is to conduct the **Mission to Planet Earth**. This is not a traditional science program. This is not a program in which we are trying to incrementally increase our knowledge of the Earth. This is a crash program designed to rapidly expand our knowledge of the Earth so that we can provide the scientific basis for sound policy decisions.

As part of this program, NASA will launch some 19 Earth science missions over the next few years which will increase our knowledge of the Earth. We will construct a major data system that will come on line in the 1994 time frame to be able to incorporate the data from these upcoming missions (and from past missions) so that we learn as much as we can about the Earth and how it works. And we will double our support for basic research in Earth science.

But to understand sufficiently how the Earth works so that we can predict its future, we must develop an understanding of how the Earth works as a coupled system. Consider, for example, aspects of greenhouse warming. Carbon dioxide from industrial pollution is growing in the atmosphere and has the potential of increasing the temperature through greenhouse warming. However, the amount of carbon dioxide in the atmosphere depends on the amount absorbed by the Earth's biota. The response of the atmosphere to increased greenhouse warming may depend on whether there is a change in the cloud cover of the Earth, and at what altitude the clouds form. The response of the climate, in particular regional effects, will depend on changes in the global circulation of heat through the oceans. Indeed, the response of the Earth to human interactions will depend on the coupling and interactions which occur among the various components of the Earth. These couplings generate feedback mechanisms that could either enhance or mitigate the effects of global change. The essential challenge to us, then, is to understand which feedback mechanisms are dominant, and how the Earth will respond.

The Earth science missions that will fly in the next few years will not yield definitive answers to how these coupling and feedback systems of the Earth work, and thus to how the Earth will respond to global change. In some cases the instruments that will fly have inadequate resolution and sensitivity. More important, they will not provide comprehensive observations of the components of the Earth at the same time. It is a simple reality that to understand how the oceans and the atmosphere and the biota interact and are coupled, it is necessary to observe the changes in these components, and the resulting responses in other components, at the same time.

To provide comprehensive observations of the Earth as a system, NASA will fly the **Earth Observing System**, or **EOS**. Two well-instrumented platforms in polar orbit, together with platforms from Europe and Japan, will provide comprehensive, long-term observations of the interactions among the components of the Earth, so that we can understand how the Earth works and project how it will respond to our continuing influence.

The cost of Mission to Planet Earth is considerable -- it is comparable to all the other science programs in NASA combined. Yet compared to the value of the information, the cost is minuscule. Mission to Planet Earth contributes to the scientific basis designed to support policy decisions focused on protecting both the global environment and the world economy.

I would like now to elaborate on several aspects of Mission to Planet Earth.

1. What are the components of Mission to Planet Earth?
2. What is the Earth Observing System (EOS)?
3. Why must some instruments fly together?
4. How will NASA process the data from EOS?
5. What is NASA doing to get ready for EOS?
6. What role does education play in EOS?
7. How much will EOS cost?

What are the components of Mission to Planet Earth?

The President has proposed in the FY 1991 budget an aggressive, multi-agency research program to reduce the scientific uncertainties associated with global change. This program was developed by the Committee on Earth Science, a Federal interagency committee formed under the President's Science Advisor. With unprecedented cooperation, agreement, and a clear consensus, representatives of thirteen Federal agencies formulated the strategy for the U.S. Global Change Research Program. The priorities of this program are to document change in the Earth system using observational programs and data management systems, to carry out focused studies on controlling processes to improve our understanding, and to develop integrated conceptual and predictive models.

NASA's programs are central to the mission of the U.S. Global Change Research Program. Our major role is to apply our expertise in remote sensing to use the global perspective that is available only from space to understand how the Earth works as an integrated system. We call our program Mission to Planet Earth. It consists of (i) some nineteen near-term flight missions that will expand our knowledge of aspects of global change; (ii) an integrated data system that will be available by 1994 to draw maximum information from existing and upcoming missions; (iii) an expanded scientific research program; (iv) a series of small, focused missions known as Earth Probes; and (v) the Earth Observing System (EOS), which will provide comprehensive long-term observations of the whole Earth and its component parts, sufficient to serve as the basis for predictive models of the future of the planet.

Mission to Planet Earth is unlike any other NASA Space Science Program. It is intended to broaden, with all due haste, our understanding of all aspects of the Earth system -- to broaden our understanding to a point where we will have sufficient knowledge of the intricate elements of the Earth system to make sound policy decisions. This program will require substantial and sustained funding levels, and will dwarf any other Space Science activity.

What is the Earth Observing System (EOS)?

The Earth Observing System (EOS), the centerpiece of the Mission to Planet Earth and an essential component of the President's U.S. Global Change Research Program, will provide U.S. leadership in the search to understand our environment. The science program for EOS reflects an integrated observational approach to many of the difficult science questions which face us while providing a direct response to the science priorities defined by the U.S. Global Change Research Program.

It is important to realize that EOS is a research program, which is designed to yield the maximum information about the Earth, and any impacts due to human activities, in the shortest possible time. It provides for a data and information system that will enhance the return for past and current missions, and missions that will fly in the next few years. It provides for an immediate and substantial growth in support for scientific research. It provides the comprehensive long-term global observations necessary to understand how the Earth responds to human interactions. In fact, a major potion of the funding for EOS will support the acquisition and analysis of data, and its scientific interpretation.

Only 40% of the funding is for space hardware. This is unprecedented in terms of funding distribution for space science programs. In planning this program, we recognized early on that the need to acquire data in an expeditious manner -- a manner which would support policy makers in their decision process -- warranted an aggressive program relative to data acquisition and analysis.

In order to meet the measurement goals of EOS science, the EOS program consists of two series of polar orbiting platforms with complementary payloads launched on Titan IV expendable launch vehicles. Each platform will be replaced every 5 years to achieve the 15 year mission lifetime goal.

The EOS platforms are designed to provide the comprehensive global observations to understand the Earth as an integrated system. The first platform, which will launch in FY 1998, is devoted to measurements of the surface of the Earth, and to the conditions of the lower atmosphere. The second platform, which will fly two and a half years later, is devoted to measurements of the chemistry of the upper atmosphere, the circulation of the oceans, and the behavior of the solid Earth. In addition, our international partners, the European Space Agency (ESA) and Japan, are planning to build platforms which include accommodations for U.S. scientific instruments.

The requirement for global coverage from EOS dictates that these instruments be flown in a near-polar orbit. To avoid biasing EOS observations with the combined effects of diurnal and seasonal effects, sun-synchronous orbits have been selected for EOS. The 705-km, 98.2 degree inclination orbit planned for EOS will provide a quasi-two-day repeat pattern for frequent global coverage, while being in an altitude range acceptable to both wide-swath-width and high-resolution instruments.

The equator crossing time for EOS has been selected as 1:30 pm ascending node. This choice ensures strong solar illumination to improve the signal-to-noise performance of instruments measuring reflected sunlight. It is also designed to provide observations of terrestrial vegetation under conditions of near-maximum thermal and water stress. This choice of orbit also means that those EOS instruments with operational potential will be flown under conditions that are close to those of the primary NOAA polar operational mission.

The proposed payload groupings are the result of extensive analysis of accommodations, science requirements, international partner plans, cost, schedule, and other factors. The final allocation of instruments and other payload elements to specific platforms will be in accordance with selection confirmation decisions to be made in September 1990 for EOS-A and approximately one year later for EOS-B.

Why Must Some Instruments Fly Together?

Within the overall payload of EOS, there are sets of instruments which can complement each other in the production of desired observations. In some instances, certain instrument suites are required to yield corrective data. To do this, they must make their measurements simultaneously. These sets dictate certain minimum payload groupings around which alternative scenarios have been built and assessed. The time scales for significant variations in the phenomena being observed define the meaning of simultaneous. For EOS, there are four levels of simultaneity, which are detailed in the following paragraphs.

First, all EOS instruments need to be in orbit at the same time. This enables many of the variable components of the Earth system to be characterized globally every 1 to 3 days. This requirement is the reason behind the extensive set of planned observing capabilities. While many aspects of the Earth do not change on the time scale of days, all of the EOS instruments observe dynamic phenomena that do change rapidly.

Second, the atmosphere changes on time scales as short as 10 seconds. Changes in aerosol concentrations, temperature, water vapor distributions, and clouds can significantly affect the atmospheric contribution to signals received by optical instruments. This imposes simultaneity requirements on three separate sets of instruments to make their observations within a minute of one another and from the same perspective.

o The first group of these instruments includes those that measure the troposphere. If observations are made at the same time, data from these instruments can be combined to produce improved algorithms for atmospheric temperature and moisture profiles, cloud properties, aerosol column densities, and instantaneous rain rates.

o The second grouping includes the optical surface imagers. Although each of these imagers operates at different spatial resolutions, they share specific spectral bands. Surface imaging optical instruments always employ atmospheric corrections. For example, if the Moderate-Resolution Imaging Spectrometer (MODIS) and the High-Resolution Imaging Spectrometer (HIRIS) view the surface through the same atmosphere (i.e., simultaneously and from the same perspective), their data will be directly intercomparable before atmospheric corrections are applied. This will remove a major source of potential ambiguity from the results of such intercomparisons. Furthermore, the atmospheric corrections of the optical surface imagers may be aided by data from the atmospheric sensors in the first group.

o The third group of instruments are those that measure the different components of stratospheric chemical composition. If these instruments view the same stratospheric air mass at the same time, chemical concentrations from one instrument can be reasonably combined with those from another for a more comprehensive set of observations to use in comparison with localized photochemical models.

Third, vegetation canopies respond to environmental conditions on many time scales, but typical responses to drying conditions and variations in insolation may take as little as an hour. Consequently, those instruments used to study terrestrial vegetation need to make their measurements of a given site within an hour. This set of instruments includes all surface imagers within the proposed EOS payload. If these instruments are on platforms in the same orbit, even if they are on more than one platform, they can have the opportunity to view the same sites within 1 hour of each other. If they are flown in different orbits, there would only be intermittent opportunities for simultaneous viewing within the time requirement.

Fourth, measurements produced by the EOS Altimeter (ALT) and the Geosciences Laser Ranging System (GLRS) instrument both require precise knowledge of spacecraft location. The Global Positioning Satellite (GPS) Geoscience Instrument (GGI) on EOS is intended to provide this information. Flying these three devices on the same spacecraft allows them to share spacecraft location information.

The platforms are sized to accommodate those instruments which need to observe the Earth simultaneously, through the same column of air. All instruments that observe the surface of the Earth require substantial atmospheric corrections; knowledge of aerosol content, temperature, water vapor, etc. Thus, it is important to fly all the surface imagers and the instruments which determine atmospheric conditions on the same platform. This requires a total of eleven instruments, approximately 3000 kg of payload, to be flown together. This number of instruments is approximately equal to the number accommodated on the Upper Atmosphere Research Satellite (UARS); however, given the complexity of the EOS instruments, the total payload weight is 30% greater than that of UARS. In addition, EOS has the capability to manage over 10,000 times more data than UARS.

We have sought the constant advice and review of the Earth science community on the design of EOS, the choice of instruments, and the approach toward scientific research and data processing. In particular, the science community has consistently noted that a long-term, comprehensive set of simultaneous observations are the key to the success of the EOS program. Our fundamental concerns are assuring that the instruments are available in a timely fashion, and ensuring that our program meets the scientific priorities and requirements laid out by the U.S. Global Change Research Program. The size of the platforms, and their timing for launch, are simply an outgrowth of these science requirements. The challenge of the EOS platforms is directly related to the development, testing, and integration of the science instruments on those platforms, not the management of the platforms or the number of platforms which are built.

We will need to track the global environment for some years to ensure that we understand the changes, and the processes responsible for them. EOS is designed to yield fifteen years of continuous data. Since the EOS platforms are in polar orbit, where there is no servicing from the Shuttle, and a reasonable design life for a spacecraft is five years, each EOS platform will be replaced on orbit twice by an identical platform, at five year intervals.

How Will NASA Process the Data From EOS?

The EOS Program has put a major emphasis on the EOS Data and Information System (EOSDIS). EOSDIS is planned to acquire a comprehensive, global, 15-year data set, to maximize the utility of this data set for scientific purposes, and to facilitate its easy access by the research community. In addition to data processing, archival, and distribution facilities, the EOSDIS includes the necessary capabilities for the command and control of the spacecraft.

The development of EOSDIS will be initiated immediately by building on the existing infrastructure within the research community. It will implement an architecture which is open and distributed, so that it can evolve with advances in computing and networking technology. The near-term objectives are to support the research and analysis of data which both exist and will come from the near-term pre-EOS missions. In this way, the research community can gain valuable early experience in preparation for the future large EOS data volume.

Archived data sets, in addition to those from the EOS satellites, will include complementary in situ and satellite data. EOS will also involve the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, the National Science Foundation, and other agencies.

There will be two types of data products: standard and specialized. Standard products will be generated and archived at Active Archive Centers around the country (all of which are existing data archives); the target time for the availability of engineering-level products is within 48 hours of collection, while the target for derived geophysical products is within 96 hours. Specialized products will be generated by individual investigators and made available to EOSDIS for archiving and distribution, as appropriate.

The EOSDIS data policy specifies that all data and derived products be available to all research users, with no preference given to EOS investigators. Research users in the U.S. and participating countries will pay only the nominal cost of data reproduction and delivery; they will be required to agree to publish their results and to make available supporting information, including methods for analyzing data. Research users in other countries may propose cooperative projects and associated "in kind" contributions (i.e., provide similar access to appropriate satellite, aircraft, and surface-based data) in exchange for access to EOS data on similar terms. Access to the raw data stream will be provided to operational agencies for forecasting purposes. NASA will provide for the commercial distribution of data on a non-discriminatory basis to all other users.

What is NASA Doing to get Ready for EOS?

During the next several years, our knowledge of the Earth will increase substantially. NASA will execute 19 Earth science missions, which will study various aspects of how the Earth works. The Upper Atmospheric Research Satellite (UARS) will make definitive measurements of the chemistry and dynamics of the upper atmosphere, and thus of ozone depletion. A series of Total Ozone Mapping Spectrometer (TOMS) instruments, with potential flights in 1991, 1993 and 1995, will measure atmospheric ozone concentrations and contribute to our current models. The joint U.S./French TOPEX/POSEIDON mission will reveal more about the circulation of the world's oceans than all the ships in history. The NASA Scatterometer, to be launched in 1995 aboard the Japanese ADEOS spacecraft, will study wind stress on the oceans. The ATLAS Spacelab missions will study the atmosphere, and Shuttle Radar Lab, the topology of the land. Numerous Earth Probes missions in addition to TOMS are proposed; small missions in Earth science to pursue focused problems, e.g. the Tropical Rainfall Measuring Mission and an Ocean Productivity Experiment. Also, our international partners, the Japanese, Europeans, and Canadians, will launch seven missions, some of which will carry U.S. experiments, and many of which we will help track in return for access to their data. In addition, NOAA will continue to operate meteorological satellites.

To make optimum use of the data from these upcoming missions, we need to improve the computational capabilities in Earth science, and the access of researchers to this data through networks and archiving facilities. Included in the funding for EOS is substantial support to develop the EOSDIS, essential elements of which will be brought online in the early 1990's, in advance of the launch of the EOS platforms. EOSDIS will be used to derive maximum information from existing and upcoming missions; in turn, the data from these missions will be used to test and perfect EOSDIS in advance of the larger data flows from the EOS platforms.

What Role Does Education Play in EOS?

Data alone, of course, does not yield understanding. That will require scientists interpreting the data, developing concepts for the processes which control the Earth, and building predictive models of its future. EOS also includes funding to effectively double the research community that will dedicate itself to understanding global change, and the program will support graduate fellowships to insure continuity of this research base into the future. The funding for scientific research has been included from the inception of the EOS program.

Education is the key to successfully addressing the habitability of our planet over the long term. The upcoming 19 Earth science missions mentioned earlier can be the conduit to educate the public, and particularly the young, about the importance of the Earth's processes. As with other space missions, EOS and other Earth science efforts will encourage young people to take up science and math with a concrete goal in mind -- working for the Earth.

For example, we have identified specific funding in the EOS budget to establish an Earth Science Fellowship Program. Starting with 25 fellowships to be awarded in 1990, the program will fund up to 150 graduate students per year for the duration of the mission. The EOS Fellowship program will increase the number of Earth scientists and engineers. A national competition is planned to recommend and make awards for research support to graduate students enrolled in full-time Ph.D. programs at accredited U.S. universities.

Awards will be made for an initial 1-year term and may be renewed annually up to 3 years, based on satisfactory progress as reflected in academic performance and evaluations by the faculty advisor. Applications will be considered for research on global biogeochemical cycles, radiation and physical climate interactions, the hydrological cycle, and solid Earth processes. Atmospheric and ocean physics, chemistry and biology, ecosystem dynamics, soil science, geology, geophysics, and cryospheric processes are all acceptable areas of research, providing that the specific research topic is relevant to NASA's global change research efforts (the Earth Observing System and Mission to Planet Earth).

How Much Will EOS Cost?

EOS will be the largest space science mission ever undertaken. Through the year 2000, the cost of EOS, including the instruments, the platforms, the data system, and the support for science, is approximately $17 billion in real year dollars (inflation included). The cost of all the EOS platforms and instruments, for example, is equal to what has and will be spent on the four Great Observatories for astronomy.

However, the key difference between EOS and other space science missions is how the money will be spent. In the EOS program, 60% of total funds will support ground operations, data and most importantly science. On most major missions, the majority of the funds goes for space hardware with only 30% allotted for science and data. The EOS cost ratio is driven by the volume of data, i.e., nearly 50,000 terabytes, and our determination that EOS produce reliable predictions of the future as soon as possible.

The EOS program will be managed by the Goddard Space Flight Center (GSFC). The FY 1991 budget includes funding to augment the workforce at GSFC in direct support of the EOS program and begins funding necessary to undertake construction of an EOSDIS facility. Both of these elements are integral to the total EOS program and required for its timely initiation.

However large the cost of EOS is in comparison with previous space science projects, its cost is truly minuscule compared to the cost of taking the wrong action on global change. For example, estimates for the cost to substantially reduce fossil fuel consumption can exceed a trillion dollars per year to the world's economy. EOS will give us the information to chart a course that both protects the environment and the economy.

SUMMARY

Mr. Chairman, we have a responsibility. We know that we are affecting our global environment, yet the outcome of these effects on the world that we will bequeath to our children and our grandchildren is unknown. We cannot let this ignorance persist. We need to undertake the Mission to Planet Earth and the entire global change research program of the federal government so that we can reduce the uncertainties in the pending global changes, and be, as a result, wise stewards of the future of the planet.

Thank you, very much.

Responses to written questions submitted by Chrm. Gore resulting from the April 3, 1990, hearing.

As we discussed at the hearing, there have been reports that the House Budget Committee may recommend funding levels for NASA that are $1 billion below the President's request.

Question 1: If the number and type of instruments for the Earth Observing System (EOS) had to be reduced, how would the scientific value of the program be diminished? Could the scientific priorities be met with a more constrained program?

Answer 1: The sensor payload for the EOS-A platform has been designed to incorporate a critical complement of instruments which will enable simultaneous observations of various surface features, while being able to also characterize the atmosphere through which these observations are being made. The platform has been sized to accommodate those instruments which need to fly together to make these simultaneous observations and to provide the critical understanding needed for significant progress in global change research. The scientific community has carefully and extensively reviewed the design of EOS, the choice of instruments for the platforms, and the approach toward scientific research and data processing. In particular, the science community has consistently noted that a long-term, comprehensive set of simultaneous observations is the key to the success of the EOS program.

A reduction in the number or type of the payload instruments would seriously endanger this objective and diminish substantially the ability of the EOS mission to meet the objective of the U.S. Global Change Research Program. Because the observations from many of the instruments are designed to be made simultaneously and to be analyzed together, the loss of instruments would result in a loss of science far in excess of the losses which one would expect for the individual instruments themselves -- the synergistic effects of the payload complement would be drastically reduced.

The EOS mission has been carefully planned to accomplish the necessary science at the lowest possible cost. We would view a significant reduction in the funding for the program as a serious threat to the program's viability.

Question 2: If the EOS Program was forced to accept a significant reduction in its FY 1991 program, what options would be available to you?

Answer 2: As with any major space science program, adequate early year funding for EOS is critical to maintaining the schedule for data system and hardware development and launch and to reducing the risk of out year cost growth. A significant reduction in FY 1991 funding for EOS could delay launch up to a year and cause similar delays in major EOS Data and Information System (EOSDIS) deliveries. Such delays would postpone the important observations of EOS and delay the time when the science community will have the full capability of the EOSDIS.

Some observers in the space science community warn that EOS could become a "Christmas Tree" -- that because of its size and scope, the affected scientific community will be forced to include more and more capability in a single mission for fear of having no alternative. My concern is that this approach could lead to increased costs, cause schedule slippage, and ultimately diminish the mission's productivity.

Question 3: What steps are you taking to ensure an appropriate limit to the scope of the EOS program, in order to bring it in at cost and on schedule?

Answer 3: The Earth Observing System (EOS) has been carefully designed by NASA, in close cooperation with the scientific and technical community, to respond to the specific requirements agreed upon by the interagency Committee on Earth Sciences (CES) in their design of the U.S. Global Change Research Program (USGCRP). Neither the Earth Observing System nor the USGCRP are meant to provide unlimited opportunities for research. Instead, the USGCRP is focused on those priority areas of study which are most essential to rapidly improving our understanding of the nature of the Earth's environment and the dynamics of global change. Each participating Federal agency has a designated area of research for which it is most suited to conduct. The USGCRP is designed to assure that the appropriate scientific scope is achieved by maximizing existing expertise and research experience.

Various steps are being taken to assure appropriate management of cost and schedule for EOS, e.g. constraining the initial instrument selection to meet present funding levels and the specific science objectives of the U.S. Global Change Research Program. During Phase B activities over the last year, several of the instruments have gone through extensive reviews and modifications to help reduce while still providing the necessary science. The program-level requirements partition the science, data system, instruments and observatories in a manner that provides independent Headquarters analysis and interaction with the appropriate project-level managers but has a single integration and control activity within the Program Office.

As you have heard from our first panel, the National Research Council (NRC) has expressed its concern that the synthetic aperture radar -- the only instrument with the potential to measure soil moisture and global biomass -- has not been included in NASA's FY 1991 budget.

Question 4: When will NASA's budget reflect funding for development of the synthetic aperture radar?

Answer 4: NASA's budget includes funding to continue the highly successful Spaceborne Imaging Radar (SIR) Program. This series of synthetic aperture radars (SAR) has flown aboard the

Space Shuttle (SIR-A in 1981, SIR-B in 1984) and provides precursor missions for the EOS SAR. The next mission, SIR-C, is scheduled for flight in 1993 and should demonstrate the multi-frequency, multi-polarization SAR needed to obtain the measurements cited by the National Research Council. As part of the SIR Program, we are providing a low level of funding for limited definition studies of the EOS SAR. It is our plan to increase our understanding of the technical challenges and risks in building a radar of this type through the experience gained from the SIR-C development prior to submitting a new start request for funding. This approach suggests possible inclusion of the SAR in the FY 1994 budget request as a new start, with a potential launch of a SAR in the year 2000 time frame as part of the EOS system.

Question 5: Further, the NRC stated that based on engineering considerations, the SAR instrument may not be compatible with the EOS platform. Do you agree with the suggestion that SAR may have to be made a separate free-flying mission?

Answer 5: As we performed definition studies of the instruments proposed to be incorporated into the EOS-B platform, we did find incompatibilities between the SAR requirements (primarily in power, mass and data rates) and the multiple instrument concept on a standard EOS platform. As a result, we are currently planning the SAR as a free-flying mission with the orbit and platform designed expressly for acquiring SAR data in the optimum manner.

We have been hearing a lot of complaints from our international partners on the Space Station Freedom program. They argue that the U.S. often decides what scientific questions it wants to answer, dictates how it wants to answer them, and only then brings in foreign partners to help pay for the research.

Question 6: Is the situation any better with EOS? What is being done to ensure better communications with foreign nations?

Answer 6: On both the Space Station Freedom and EOS projects, the United States is working with other nations as a cooperative and responsive partner. In both cases, while the U.S. is making the largest contributions, it is also conducting ongoing discussions on planning and design with its international partners and incorporating their suggestions and requirements.

The EOS polar platforms represent a clear example of this cooperation and coordination. While the design and development of each polar platform series is generally under the unilateral control of one of the EOS partners, the partners have worked closely with each other to ensure their efforts do not overlap. Platform design and capabilities were the subject of extensive discussion and review by the international partners through the Task Force on Scientific Uses of the Space Station (TFSUSS) and the International Forum on Scientific Utilization of the Space Station (IFSUSS).

At the same time, planning for EOS science and instruments was being coordinated among the partners (U.S., European Space Agency, Japan, Canada) through the Earth Observations International Coordination Working Group (EO-ICWG). These meetings have been productive and open, leading to significant progress on coordinated science and mission goals. Moreover, researchers from all over the world had the opportunity to participate in EOS science efforts through the open Announcements of Opportunity (AO) process used to identify and select EOS principal and interdisciplinary investigators.

Within the individual partners' countries, the approach to planning for Earth observatories (and EOS) has varied. In the United States, the scientific community has been closely involved in developing the specific science requirements for the EOS platforms and in recommending how best to meet such requirements. The U.S. approach is oriented toward a program of global observations, leading to a clearer scientific understanding of the nature of global change. The European Space Agency and the Japanese approach is focused on observations directed at applications of data to immediate environmental and operational use. These applications measurements complement the research measurements and are clear contributors to developing a comprehensive and long-term global data set of Earth observations.

Question 7: Just how important are the polar platforms that are planned by the Japanese and the ESA? I understand that most of the instruments are not as advanced as those on the U.S. platforms. How different are they? How important is that difference?

Answer 7: The polar platforms to be provided by our international partners are an important part of the overall global change research effort, and their capabilities have been incorporated into the U.S. planning efforts. The key to success for the EOS program is coordination - both within the U.S. government (through the efforts of the CES) and in the international arena. The EOS effort will be most successful with contributions from many nations, with each focusing on specific activities which take advantage of that nation's scientific expertise.

While the U.S. remains the technological leader in many areas of Earth remote sensing instrumentation, the need for "state-of-the-art" technology in the study of global change using satellites varies widely. The focus of observations for the EOS partners tends to be operational rather than research. One consequence is that the international instruments are often less "advanced" than many of those proposed for flight on the U.S. polar platforms. This does not mean that these instruments and platforms are not important. On the contrary, the different observational perspectives afforded by the international platforms, combined with the ability to exchange instruments among the platforms, makes each of the partners' contributions an important component in conducting global change research. All observations are important in compiling the crucial long-term database needed to better understand the Earth.

Like the scientific community, industry has a great deal of interest in the data collected by EOS.

Question 8: What are your plans for allowing access to data by for profit users planning to undertake research? Further, what provisions will be made to allow access to EOS data by commercial users?

Answer 8: EOS planning allows for access to EOS data by all users in a timely manner. NASA's announced data policy for the EOS time frame is to provide access to bonafide researchers at the marginal cost of reproduction and delivery. All researchers are expected to publish their results in the open literature and to fully disclose the methods used to produce these results. Design of the data access policies will incorporate requirements of the Land Remote Sensing Commercialization Act (PL 98-365), especially as they relate to for-profit users.

Senator Gore. Thank you very much.
Dr. Corell.

STATEMENT OF DR. ROBERT W. CORELL, ASSISTANT DIRECTOR, OFFICE OF GEOSCIENCES, NATIONAL SCIENCE FOUNDATION

Dr. Corell. Thank you, Senator. It is a delight to be back and to discuss the U.S. Global Change Research Program with you. I come with really two hats: one as a Vice-Chairman of CES, Committee on Earth Sciences, and also Chairman of the CES Global Change Working Group. I thought I might say a few things about that, but I also am the responsible person at NSF to whom you may address questions concerning NSF's global change interests.

In effect, I would like to give you a progress report on what has happen since we last discussed this across the hearing table. You better than virtually anyone in the Congress, know the nature of the dynamics that this planet Earth is facing. The planet is a dynamic system. It is changing on a wide variety of time scales and spatial scales. Although there is much uncertainty about their relative contributions, both natural and human activities are clearly influencing these changes.

As we have said before, it is vital that a scientific understanding of how the Earth's systems function on a global scale. This is a vital next step for our Nation and our partners abroad. Specifically, we see an immediate challenge to expand our understanding of the basic mechanisms and interactions and to ultimately develop the predictive capability to understand how environmental changes occur, how we, the inhabitants of this planet, affect those changes, and how natural variability is the context within which all that takes place.

Wise policymaking, in our judgment, requires improved scientific understanding and knowledge of the economic context in which it fits, so that the actions for the future that this Nation and others undertake are done in a responsible context of science, economics and policy.

Toward that goal, the President's 1991 budget proposes spending $1,034,000,000 on the U.S. Global Change Research Program almost a 60 percent increase over current funding levels for that activity. You might ask what is new, what is different, what is here today that was not at the table when we discussed this with you some months ago.

There has been an intense effort over the last year to thoroughly review, the details of the research programs of the seven principal agencies that compose the U.S. Global Change Research Program. After doing that, we developed a framework within which decision-making can progress and recommendations can be made, to both OMB and the agencies, about how to build an integrated global change research effort that will support the policy process. That framework involves several elements.

First, the development and understanding of the role that each agency plays in the global change effort. It is not just a collection of agencies interested in global change. It is the result of a deliberate effort to define specifically what NSF, NASA, NOAA, USGS and the other partners do. It was an interactive process in which OMB, the agency heads, the CES and OSTP all played a vital part. In the end, each agency agreed to the role they, themselves, play and the roles the other agencies play.

That may seem like a small development, but in my judgment, Senator, it was a crucial step in developing this program. Because of that effort, we have not faced the traditional turf battles that often exist between agencies, for we know what each other's part is, we know how the complex jigsaw puzzle of interagency activities fit together, and when you put that on the table there is some sense of wholeness about it.

A second important dimension of the framework was the involvement of the executive branch at the White House—the executive offices of the White House having been strong partners in the development of the Global Change Research Program, OMB and OSTP in particular. At OMB we have a companion organization, to CES. The examiners for the agencies who are partners to the Global Change Research Program are connected and work with and through a chairman inside OMB so that the same process that is occurring on the outside has a mirror on the inside of OMB. That is done with the full support, knowledge, and coordination of OSTP.

Another new element in the Global Change Research Program is a set of priorities that grew out of and in concert with the scientific community. These priorities were placed in our report of last summer, the so-called blue book. The priorities identify the major areas of scientific uncertainty and the gaps in knowledge. That priority framework was not the product of a group of bureaucrats who decided how to implement their programs, but was a direct product of a detailed interaction between bureaucrats and the scientific community.

Recently the Academy has throughly reviewed that priority framework and has joined us in identifying it as a framework within which they, too, can function. Things like the role of the clouds, the ocean and so forth come high in the priorities. The framework provides us the basis for developing our budgets, and identifying where our major resources are going to be allocated.

Another element that is new is a set of criteria which we are going to use to determine programs of high priority, by looking at how those scientific elements within the program are developed, if they have gone through a peer review development process, if they are ready, and if they are cost effective. All of these criterion are identified for you in the "gray book", ["Our Changing Planet: The FY 1991 U.S. Global Change Research Program"].

Lastly, we entered into an agreement between the CES, OMB and all of the participating agencies. A contract was developed and agreed to by all the partners which identified the role of the agencies, the role of CES, and the role of OMB. That gave us a set of machinery to manage the development of a comprehensive, unified, governmentwide scientific program that we call the U.S. Global Change Research Program.

We can explore the management implications of that, if you wish, but it is my judgment that this is a unique approach to the development of a comprehensive program of science that allows for tight management within the agencies while at the same time being able to field a coordinated and integrated program.

Thank you.

[The statement follows:]

STATEMENT OF

ROBERT W. CORELL
ASSISTANT DIRECTOR FOR GEOSCIENCES
NATIONAL SCIENCE FOUNDATION

GENERAL BACKGROUND

The Earth's environment is a dynamic system that changes on widely varying time and space scales. Although there is much uncertainty about their relative contributions, both natural phenomena and human activities are influencing these changes. It is vital that a scientific understanding of the Earth system be obtained on a global scale by describing how the environment's component parts and their interactions have evolved, and how they may be expected to evolve in the future.

Specifically, the immediate challenge is to understand the basic mechanisms and interactions and ultimately develop the capability to predict natural environmental changes and to see if there are others which may be influenced by man. Wise policy-making requires this improved scientific understanding of our planetary life support system.

To move toward that scientific understanding, the President's FY 1991 Budget proposes spending $1.034 billion on the U.S. Global Change Research Program, an increase of $375 million or 57% over FY 1990. Nearly half of the proposed increase, $172.4 million, is associated with support for two NASA initiatives -- the Earth Observing System (EOS) and Earth Probes, programs that Dr. Fisk will be addressing in his testimony. About 13% of the increase, or $48 million, is for the National Science Foundation, 18% for NOAA, and smaller percentage increases for the other four CES agencies.

Details of current (FY 1990) and proposed (FY 1991) spending by agency in support of the U.S. Global Change Research Program (USGCRP) are presented in **Appendix A**.

The USGCRP represents an integrated, Government-wide scientific effort designed to document, understand, and predict changes in the global environment as the foundation for national and international policymaking. The following summary reviews the development of the Program to date and characterizes the nature of the FY 1991 request.

BACKGROUND

In March 1987, William Graham, then-Director of the White House Office of Science and Technology Policy (OSTP), established a new Committee on Earth Sciences (CES) under the Federal Coordinating Council on Science, Engineering and Technology (FCCSET). CES was, to a great extent, created in response to the recommendations of a Domestic Policy Council Ad Hoc Working Group on Climate Change which, in late 1986, concluded that improved mechanisms for Government-wide coordination were required for the U.S. to position itself to effectively address the significant economic, social, and environmental issues raised by changes in the global climate system. Focused primarily on the coordination of U.S. scientific activities, the CES was created to:

> Increase the overall effectiveness and productivity of Federal R&D efforts directed toward understanding the Earth as a global system.

Membership of CES was designed to include the principal earth sciences funding agencies (NASA, NSF, Commerce [primarily through NOAA], Energy, EPA, Interior, and USDA), as well as other Departments, Agencies and Executive Branch offices with interest in the policy and budgetary implications of such research (State, Transportation, CEQ, OSTP, and OMB). CES is currently chaired by Dr. Dallas Peck, Director of the U.S. Geological Survey. I serve as Vice-Chair of the Committee and Chairman of the Working Group on Global Change.

The CES has a number of specific areas of responsibility, including coordination of Federal activities in groundwater research, natural hazards reduction, and atmospheric research. However, the primary focus of the Committee's efforts to date has been the development of the U.S. Global Change Research Program and provision of an integrating focus for scientific input to national and international global change policy deliberations.

THE U.S. GLOBAL CHANGE RESEARCH PROGRAM

The U.S. Global Change Research Program was formally announced in a January 1989 CES Report entitled, *Our Changing Planet: A U.S. Strategy for Global Change Research*, which accompanied the President's FY 1990 Budget request. That report defined the goal, objectives, and scientific framework for the USGCRP and provided a budgetary crosscut which identified how individual agency proposals for FY 1990 fit within that framework. It is important to note that the individual agency proposals identified in that Report had been developed prior to the explicit definition of goals and objectives for the overall National USGCRP effort. Using existing scientific planning documents (including reports of the National Academy of Sciences, agency-specific review panels like NASA's Earth Systems Sciences Committee, and the International Council of Scientific Unions), and operating in the context of CES discussions about ongoing programs and research requirements, departments and agencies developed FY 1990 budget proposals in parallel with the development of the overall strategic outline of the U.S. Global Change Research Program.

In some cases, agencies such as NASA and NSF, had taken steps to initiate "earth system science" programs even before CES was created. Thus, while FY 1990 represents the official start of the USGCRP as a Presidential initiative, the FY 1991 proposal represents the first time the CES agencies could develop and present a truly integrated national Program based on a critical review of agency proposals in terms of their contributions to the stated goal, objectives, and scientific priorities of the USGCRP.

The priority-setting framework used to develop, evaluate, and integrate individual contributions to the USGCRP is contained in the July 1989 CES report entitled, *Our Changing Planet: The FY 1990 Research Plan* (see **Appendix** B). According to that template, proposed activities must first demonstrate their responsiveness to the overarching goal of the USGCRP:

> **To gain a predictive understanding of the interactive physical, geological, chemical, biological, and social processes that regulate the total Earth system, and hence, establish the scientific basis for national and international policy formulation and decisions relating to natural and human-induced changes in the global environment and their regional impacts.**

Thus, a proposed project must clearly be part of a broad scientific endeavor aimed at developing a capability to not only understand, but ultimately predict, both natural and human-induced changes in the global environment in an effort to provide decision-makers at all levels with a strong scientific foundation for policy formulation. In some cases, projects will be designed to provide near-term results by focusing an aggressive, limited-duration attack on some key aspect of the earth system -- e.g., stratospheric ozone depletion or the role of ocean-atmosphere interactions in the tropical Pacific (El Nino) in determining year-to-year climate variability over North America. In other cases, projects will be designed as part of a long-term (perhaps even "permanent") national commitment to the documentation of changes in the earth system on a global scale. NASA's Earth Observing System proposal is one such initiative.

Having passed this first filter, a proposed project must then demonstrate the nature of its contribution to one of the three scientific objectives or integrating priorities of the USGCRP:

- **Establish an integrated, comprehensive program of documenting the Earth system on a global scale through:**
  - **Observational programs; and**
  - **Data management systems;**
- **Conduct a program of focused studies to improve our understanding of the physical, geological, chemical, biological, and social processes that influence Earth system processes and trends on global and regional scales; and**
- **Develop integrated conceptual and predictive Earth system models.**

Again, the ultimate focus is on providing policy-relevant information about the current and expected state of the global environment.

Finally, the priority framework provides a relative ranking among the seven interdisciplinary science elements which characterize the USGCRP and, within those science elements, identifies the most pressing scientific uncertainties in the context of the Program's ultimate goal of predicting significant changes in the global environment. Improving our ability to anticipate, assess, and address the issues associated with climate system changes is given the highest priority in the Program. However, CES recognizes the need to maintain an appropriate level of effort in all seven science elements including adequate support for the data and information management activities required by the Program.

The individual science priorities in the current research plan probably represent the most dynamic feature of the USGCRP. As new insights into earth system processes are gained, and new problems and research needs are identified in response to that new understanding, the details of the science priorities will change. In essence, the evolution of the science priorities will be a measure of the success of the U.S. Global Change Research Program.

THE FY 1991 PROPOSAL

The FY 1991 proposal is described in a 60-page document entitled, *Our Changing Planet: The FY 1991 U.S. Global Change Research Program.* In that report, the Program's current science priorities are presented in the context of a series of policy-relevant questions which are summarized in **Appendix** C. Consistent with the priority framework, the largest share of the proposed increase supports enhanced efforts in the areas of Climate and Hydrologic Systems, Biogeochemical Dynamics, and Ecological Systems and Dynamics. $118 million, or 32%, of the proposed increase is directed at improving the measurement program associated with the Program's objective to document Earth system change on a global scale. NASA's EOS and Earth Probes initiatives constitute the largest share of that increase. $150 million, or 40%, of the increase is associated with focused studies on Earth system processes; NSF's proposed increase of $48 million represents a significant share of that increase.

In all cases and for all agencies, the suite of high-priority projects that comprise the FY 1991 proposal were carefully evaluated by the CES Working Group on Global Change for their:

- Relevance/contribution to the stated goal, objectives, and scientific needs of the USGCRP;
- Scientific merit, i.e., is the proposed work scientifically sound and of high-priority;
- Readiness, i.e., is the level of planning high, the capabilities in place, and the research likely to produce early advances;
- Linkages to related national and international efforts; and
- Costs, i.e, do the identified costs represent an adequate and appropriate share of the total available resources.

Many individual projects were dropped, delayed, or amended in response to the CES review. The FY 1991 proposal now reflects a suite of individual projects which address the highest-priority scientific uncertainties and reflect the special expertise and unique capabilities of each of the participating agencies.

THE ROLE OF THE NATIONAL SCIENCE FOUNDATION

Both the Directorate for Geosciences (GEO) and the Directorate for Biological, Behavioral, and Social Sciences (BBS) contribute to the National Science Foundation's component of the U.S. Global Change Research Program. The National Science Foundation has a broad mission to support basic research at universities and national centers, across a broad range of disciplines. Thus, unlike other CES agencies which have more narrowly defined missions, the NSF Global Change Program contributes to all seven interdisciplinary scientific elements of the U.S. Global Change Research Program (USGCRP), primarily in support of university-based research. NSF is also a major contributor to the requisite geosystems databases to assemble and use data and information efficiently and effectively:

The seven scientific elements of the USGCRP are:

- Climate and Hydrologic Systems
- Biogeochemical Dynamics
- Ecological Systems and Dynamics
- Earth System History
- Human Interactions
- Solid Earth Processes
- Solar Influences

The theme that links these categories together is that of "dynamic processes." These science elements represent active, dynamic, interconnected parts of the total earth system. The acquisition of databases, both from observations and model development, will require special efforts in all of the Global Change scientific categories. It will involve a sustained effort, in cooperation with other research-supporting agencies, to collect, organize, process, and assimilate state-of-the-art models and long-term global synoptic data to understand how the earth functions as a system.

The composition of the FY 1991 National Science Foundation focused global change effort, in terms of the science elements addressed and program names, is outlined below. In addition to these focused programs, NSF supports a large body of research that contributes to the focused efforts.

National Science Foundation - Focused Programs

Climate and Hydrologic Systems

World Ocean Circulation Experiment (WOCE)
Tropical Oceans/Global Atmosphere (TOGA)
Global Energy and Water Experiment (GEWEX)
Continental Hydrologic Processes (CHP)

Biogeochemical Dynamics
- Global Tropospheric Chemistry Program (GTCP)
- Global Ocean Flux Study (GOFS)
- Ozone Depletion/UV Effects

Ecological Systems and Dynamics
- Global Ocean Ecosystems Dynamics (GLOBEC)
- Land Margin Ecosystems Research (LMER)
- Bioresponse to Climate
- Antarctic Ecosystems

Earth System History
- Abrupt Climate Change
- Geologic Record of Global Change

Human Interactions
- Human Dimensions of Global Environmental Change

Solid Earth Processes
- Geodynamics
- Ridge Interdisciplinary Global Experiments (RIDGE)

Solar Influences
- Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR)
- Geospace Environmental Modeling (GEM)

Two of NSF's programs apply to more than one science element. They are:

Arctic Systems Science (ARCSS)
- Climate and Hydrologic Systems
- Biogeochemical Dynamics
- Ecological Systems and Dynamics
- Earth System History

Geosystems Databases
- Climate and Hydrologic Systems
- Biogeochemical Dynamics
- Ecological Systems and Dynamics
- Earth System History
- Solid Earth Processes
- Solar Influences

A summary of our current thinking about these areas of research follows, with comments on NSF's contribution in each of these areas. (A more detailed outline of NSF's contributions to the Global Change Program is attached in **Appendix** D).

Climatic and Hydrologic Systems

An accurate prediction of the magnitude and timing of a change in climate (changes in the patterns of temperature, precipitation and severe weather) is limited because of a significant number of uncertainties in our understanding of the physical climate system, including: (i) how the extent and distribution of clouds may respond to a change in the radiative forcing of the atmosphere, or to a change in the aerosol loading of the troposphere; (ii) how the exchange of energy and trace gases between the ocean and the atmosphere may change, especially if the circulation patterns of the ocean change; (iii) how the exchange of energy, water, and trace gases will be impacted by changes in albedo (if there are changes in land cover, and the extent of sea and land ice) and terrestrial vegetation; and (iv) how the climate and hydrologic cycle will interact.

NSF has long supported research efforts in this area, particularly in the study of climate processes. The **World Ocean Circulation Experiment (WOCE)** and the **Tropical Ocean Global-Atmosphere (TOGA)** program are vital interagency/international programs designed to significantly enhance our understanding of climate. Both of these studies are excellent examples of cooperatively designed and implemented research programs. For example, both are integral parts of the World Climate Research Programme (WCRP), which is jointly supported by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC), and the International Council of Scientific Unions (ICSU). NSF is an important partner in these efforts, including being the lead U.S. agency for the WOCE program.

Biogeochemical Dynamics

An essential element of predicting climate change is understanding changes in the atmospheric abundance of radiatively and chemically active species such as CO_2, CH_4, N_2O, the halocarbons, sulfur and nitrogen species. This will require an improved understanding of (i) the geophysical and biological processes that control the fluxes of these species into and out of the atmosphere, from the aquatic (primarily oceanic) and terrestrial biosphere; the spatial distribution of each ecosystem; and how the geophysical and biological processes and the areal extent of the ecosystems might be altered with a changing climate; (ii) how the fluxes of nutrient species (C, N, S, and P) within, and among, ecosystems are controlled today and with a changed climate, because the fluxes of these nutrients will influence biological productivity and hence the fluxes of trace gases into, and out of, the atmosphere; and (iii) the atmospheric transformation processes of these gases which control their atmospheric lifetimes and hence abundances. While policy options may exist for controlling the atmospheric abundances of gases such as the CFCs and CO_2, they do not exist for gases such as CH_4 and N_2O because the underlying cause(s) for their current increases are not known.

One of the key questions that must be addressed is the role of the oceans in biogeochemical dynamics, particularly CO_2 fluxes within the ocean and between the ocean and the atmosphere. As one example of an NSF activity in this area, the U.S., in cooperation with five other nations are conducting a major oceanic program entitled the **Joint Global Ocean Flux Study (JGOFS)**, to address this question. JGOFS has conducted the first of several important experiments, the "North Atlantic Bloom Experiment" as a precursor to a broader set of studies throughout the 1990's.

Ecosystems Dynamics

It is vital that we improve our understanding of how the productivity and distribution of terrestrial and aquatic (primarily oceanic) biota might respond to a changing climate and to other anthropogenic and natural forcings. This is especially important in a period when other factors may be changing, e.g., atmospheric carbon dioxide abundances, ultraviolet radiation levels, the chemical composition of precipitation, and tropospheric ozone concentrations.

Changes in the areal extent and productivity of ecosystems may have several effects on the climate system, including: (i) changes in regional hydrological cycling; (ii) biogeochemical dynamics including the fluxes of trace gases into and out of the atmosphere; (iii) the exchange of energy and water with the atmosphere; and (iv) albedo. Similarly, the type of distributions of biota reflect the dynamics of the climate system. An improved understanding of how both managed and natural ecosystems function and how they might be impacted by changing environmental conditions and societal actions are necessary when considering possible policy response strategies in the event of global change.

NSF has long been active in these areas, having developed a **Long Term Ecological Research (LTER) Program** during the past decade. NSF has supported the establishment of 17 LTER's throughout the North American Continent. These, along with several other programs, are designed to contribute to a broad U.S. ecosystem dynamics program. NSF's
Bioresponse to Climate Program supports research on how the terrestrial biota will respond to changes in the climate system and how biotic responses feed back to the climate system. This program also supports studies of how the biosphere and atmosphere interact through biotic influence on composition and concentration of trace atmospheric constituents, and research on ecological responses to changes in environmental conditions.

Earth System History

Two key questions currently being asked are: (i) is the Earth's climate currently changing, and, if so, is it outside of expected natural variability and (ii) what is the reliability of the predictive models? To answer the first question requires a quantitative measure of the natural variability of the Earth's climate over both short (decades to centuries) and long (millennia) time periods. The natural variability of the Earth's environment over long time scales can be deduced using a number of indicators, including tree rings; ice cores; lake, terrestrial and marine sediments including deep sea cores; and geomorphic features.

The texture and composition of soils reflect the climatic conditions under which they developed. Consequently, soil characteristics need to be mapped on a regional scale using in-situ and remotely sensed data. Paleoceanographic reconstructions of circulation patterns can be improved by deep sea drilling, and paleogeographic reconstructions of bathymetric and continental configurations can be used to study the interaction of topography, bathymetry, and climate. This historical record of the Earth's environment can also be used, within limitations, to test our models' ability to rationalize how the Earth's system should have responded to changes in the climate forcing functions on time scales of decades to centuries.

NSF has numerous programs to support studies of earth history, particularly on time scales important to understanding natural variabilities in the Earth's climate. Both the **Ocean Drilling Program (ODP)** and our recently established deep ice coring "Greenland Ice Sheet Program (GISP)" (part of the **Arctic Systems Sciences program** -- ARCSS) are important components to these scientific efforts.

Human Interactions

An analysis of how human activities may have changed the climate forcing functions in the past would contribute to an improved understanding of how the Earth's system has changed and how these changes compare to natural variability. This would include an analysis of: (i) major land-use changes such as urbanization and conversion of land for agriculture; and (ii) human activities which may have directly, or indirectly, changed the fluxes of radiatively active trace gases, and how social and economic policies influence these changes. Another key set of questions that needs to be addressed include: How would changes in regional and global climate impact human health, and energy, land use and agricultural, natural resource, and coastal zone management?

NSF is a leading agency in the support of work on human interactions with the global environment. Through the program

Human Dimensions of Global Environmental Change, research on anthropogenic forces in global change, including both direct human action and indirect social, structural, and institutional influences on such change, is supported. Humans are the driving force behind many of the global changes we are now witnessing, through the fossil fuel burning, use of chlorofluorocarbons, and deforestation. The importance of the work on human interactions to understanding global change is now widely recognized, and NSF plans a significant increase in resources in this area in FY 1991.

Solid Earth Processes

Solid earth processes are concerned with active tectonic processes such as earthquakes, landslides, volcanism, sea level changes, and sediment movement that lead to changes in surface landforms and their concomitant effect on global variations. Changes in amounts and distribution of surface runoff and standing water, changes in aerosol, particulate, and chemical loading into both oceans and atmosphere, and changes in the chemistry of weathering and soil development are all affected by the active processes. Studies focus on the magnitude of these effects, the natural limits of variation before changes become measurable, and the frequency of reaching these limits over a geologic timescale.

NSF, with its program of basic earth science research programs, is an important contributor to these studies. Its focused programs on processes within the Continental Lithosphere, such as the **Geodynamics** program, are of particular relevance.

Solar Influences

Solar variability is a major contributor to natural changes in the radiative balance, chemical composition, dynamics, and ionization of the atmosphere. Solar energy input to the planet varies significantly over a wide spectrum of time scales, e.g., 27-day solar rotation cycles and 11-year sunspot cycles. To understand the impact of solar variability on the climate system, it is important to study and interpret the geologic and historical records for changes in climate associated with solar variability, and to monitor present and future solar output in association with monitoring shorter time scale climate variations. In order to interpret the geologic and historical record of solar activity and climate change, carbon-14 production in the upper atmosphere must be more precisely defined. This will require an improved understanding of certain aspects of particle/field coupling between the Sun and the Earth's upper atmosphere.

NSF supports basic research in solar-terrestrial interactions. The upcoming "Solar Maximum," studied through a program called "Max 91," is one example. The **CEDAR** program, which focuses on coupled interaction in the upper atmosphere, is another.

Senator **Gore**. Thank you very much.

Let me go straight to the EOSDIS subject and wrap up the questions I started with the last panel. Who was in charge of EOSDIS, Dr. Fisk?

Dr. **Fisk**. At the highest level I am.

Senator **Gore**. Is there anybody with line responsibility for EOSDIS? Under you?

Dr. **Fisk**. Sure. The division on earth science which Dr. Tilford is the director of is, of course, responsible for all of our earth science program of which mission to planet earth is the largest. He has in that—and this is an important point—two separate offices: one which develops the hardware is possibilities for EOS, and one which develops the EOS data system.

You know, it is one of the issues that frequently won phases in the development of hardware programs that there is a temptation if you run into hardware troubles to steal the resources from the data system. We are not going to let that happen here, because we have separated the two management structures.

They are integrated in terms of their purpose but from a budgetary management, the EOS data system is separate from the EOS hardware program and converges only at Dr. Tilford's and my level.

Senator **Gore**. Dr. Tilford, is there anyone directly under you who is specifically in charge of the Data Information system on EOS?

Dr. **Tilford**. Yes. Directly under me there is an office headed by Dr. Dixon Butler, who is responsible for the data and information system and also for the modeling and data analysis effort that are done within the earth, science and applications program.

And at the project level—the project being done at Goddard—there is a project manager, currently, Mr. Pete Burr. And under him is a specific project relating to EOSDIS. And that individual name is Mr. Tom Taylor.

Senator **Gore**. How does the information systems branch fit in?

Dr. **Tilford**. The information systems branch—I better let Dr. Fisk address this. It is really in his preview.

Dr. **Fisk**. We have a separate division called information systems which does a number of separate functions. It funds some of the computer systems at Goddard which are used generally throughout our entire program. It is responsible for some of the networking activities we have.

And it does some generic studies of future technology on information system. However, it is not responsible for EOSDIS.

Senator **Gore**. All right. Very good.

Now, did you want to add anything to the question I asked earlier about building inflexibility to take advantage of new developments in the computer field?

Dr. **Fisk**. I think the answers that were given are quite accurate. I mean, we have tried not to put any critical technology developments into this program for a fear that they would be on the critical path. However, we do expect to profit from developments that will occur.

I think it is important to realize that you probably could not have done EOS even as little as five years ago. Because one of the important technologies that we are depending on is compact storage of data on optical disk. If we had to rely on magnetic tapes, this program would not be possible.

Dr. CORELL. That is right.

Senator GORE. I asked the earlier panel a question about the effect of significant reductions in the budget for EOS. Do you wish you comment on that?

Dr. FISK. Well, I would view it with considerable alarm. I cannot think of no more important effort that we are going to undertake than the success of—than of EOS and the earth probes program and all the activities. And as any cut in the budgets in this year or in subsequent years, when the program even gets more expensive would produce a delay in getting the necessary information to be wise stewards of this planet.

Senator GORE. The earlier panel talked about the difference between the two platforms. What is the current design of the program? Are you looking at two?

Dr. FISK. We are looking at two large platforms. The science argument for the first one being very compelling. The argument for the size of the second one is mainly on budget and engineering considerations.

The second platform divides itself into three sets of instruments: one for upper atmosphere which you need to fly together, one for ocean circulations which need to fly together and geodynamics which need to fly together. In principle you could fly them separately.

Senator GORE. On smaller——

Dr. FISK. On moderate size, not small, but moderate size.

Senator GORE. In principle, if you flew them separately could you begin getting that data more quickly?

Dr. FISK. No. I believe, you know, there is a general consensus that the most important instruments to get up early are on the first platform, which needs to be the large platform.

The reason for that is, remember, that in the case of upper atmosphere research satellite, we will fly you hours and therefore we are getting that upper atmosphere measurements starting in 1991. And the second platform is a continuation of that data.

In the case of the ocean circulation, we will fly TOPEX POSEIDON in 1992 and the second platform is a continuation of that data. The EOS-A is the new data that we need to get. And so all the emphasis is getting that one up early, and that is the one that needs to be large.

Senator GORE. And your launch date for that one is?

Dr. FISK. It is fiscal 1998 which includes late 1997.

Senator GORE. And your justification for the second platform is partly based on an assumption that if you build one, you can build a second one cheaper?

Dr. FISK. That is correct. It is also—we need to remember that there is not a launch vehicle for moderate size payloads out of the west coast. And I have an aversion to tying a program this critical to a non-existent launch vehicle. If we did not do that Galileo would already be at Jupiter.

I prefer to have this program, because we depend on this data—absolutely confident that there will be a launch vehicle there to do it. And there are only two launch vehicles that are available out of the west coast: Deltas which are unacceptable, Titan-4s which launch large payloads.

The other possibility is an Atlas Centaur IIAS which is not yet developed. It is under development by the General Dynamics Corporation and even when developed will need to be modified for EOS. And so before we tie the second platform to that program, I would need a lot more assurance that vehicle will exist.

Senator GORE. Can you provide us your analysis comparing the cost of launching a second EOS platform compared to launching smaller probes with similar——

Dr. FISK. I can even do that as we speak, if you would like the answer immediately or I can respond for the record.

Senator GORE. Well, you can give it now. But have you done a formal cost comparison?

Dr. FISK. We have done a formal cost comparison of essentially three options in addition to the base line.

Senator GORE. All right.

Dr. FISK. One is that we launch the first platform a large Titan-4 as the science requires. And the second platform on Atlas Centaur's IIAS'. And there would be three required to perform the same function as the large platform. And that is approximately a 10 percent to 15 percent cost increase. Now I should add——

Senator GORE. If you do them separately?

Dr. FISK. If you do them separately. For the accuracy of the study that is probably not significant. However, there is no evidence that it would be cheaper to do the second platform on smaller platforms.

We also considered the possibility of putting all of the missions on small platforms, breaking up even the first one. That was approximately 25 percent more expensive. And we even explored the possibility of putting them all on Deltas, which was actually not possible. You need 36 Deltas to do it, and that was about 50 percent more costly. And, of course, you would get none of the simultaneity requirements.

Senator GORE. And you are not interested in the launch capacity of another country?

Dr. FISK. I am not easily interested in that. Again, you know, you need to do this into a polar orbit. There are laws and restrictions on our launching spacecraft on other nation's vehicles. And I am not anxious, you know, to be some precedent setting event here. Because my job is to get environmental data as soon as possible.

Senator GORE. I think that is a wise decision.

What about the calculation of risk, if there was a catastrophic failure in the launch phase or a failure in orbit in insertion into orbit? Was the risk of having all the instruments on a single platform accounted for during your review of the alternatives?

Dr. FISK. Yes. I think there is a couple points important to make here. We do not have a great deal of redundancy on these instruments in the sense of overlap between sensors. Each of the sensors on EOS—aside from overlap for calibration purposes—will make a unique set of environmental measurements.

And so were we to lose even a small platform, we would lose some critical observations in global change studies and need to respond to that as quickly as possible. So any catastrophic loss would be a serious issue, whether it is a large platform or a moderate size platform.

I should add that in our judgment, the fastest way to respond to a catastrophic loss of the first platform is to have another large platform series directly behind it. We launch EOS–A; we launch EOS–B; we launch the second platform two-and-a-half years later; we launch the replacement for the first platform two-and-a-half years after that.

Having a regular series of large platforms going to orbit gives us the option that if we had a catastrophic failure on A, we could reconfigure B within two-and-a-half years after that to replace the A instruments. And that is probably the fastest way to respond to a catastrophic loss of the first platform.

Senator GORE. What about the criticism offered by some recently that a polar orbit is really not the best orbit for some of the data collection tasks?

Dr. FISK. What the polar orbit sun sinker provides you, of course, is global coverage which most people think is among the most important things that we do. Now, however, it does not provide you diurnal coverage. And to do diurnal coverage you have several options here.

You can do earth probes if they are relatively small instruments that need to be in that orbit. And we also have active discussions with our international partners about choosing other crossing times and other orbits to provide this kind of coverage.

For example, the European platform is a morning orbit, whereas our cross orbit—whereas ours is an afternoon. So simply the same global coverage will in fact be collected at two different times of day simply by making these indifferent crossing times. Excuse me, four different times a day.

And our discussions with our Japanese partners about even not putting their platform in polar orbit, because that could give us some additional diurnal coverage. But of course the main back-up for diurnal coverage is earth probes.

Senator GORE. Now as originally conceived, EOS was supposed to be closely linked to the space station program. Instruments for EOS would be attached to the space station for testing and the polar platforms themselves would be serviced by shuttle astronauts.

However, the decision to close down the west coast launch facility at Vandenberg that would have been used to put the shuttle into polar orbit, and of course since the Challenger disaster, the plans for EOS were revised. EOS will no longer be launched with the shuttle. And since EOS will no longer be serviceable, it must be designed to operate continuously for five years without maintenance.

Is that a risky change in the design of the program?

Dr. FISK. No. We did an extensive study on this issue, and we concluded that building a platform that would last for five years was well within current technology and instruments, as well.

Building for seven-and-a-half years, we examined the possibility of could we build two platforms with a seven-and-a-half-year lifetime, for 15 years, as opposed to three with a five-year lifetime, and we did not know that we could guarantee seven-and-a-half years. We felt quite confident that current technology would give you five years of lifetime.

And certainly, if you look at spacecraft, like Voyager and things like that, we certainly tend to build spacecraft to last longer than we anticipate.

Senator GORE. How much is each incremental EOS, each incremental platform?

Dr. FISK. I am sorry, I will have to answer that for the record. They get substantially less expensive. The development cost is primarily for the first one. And I will have to break it up by dollar numbers for you, for the record.

[The following information was subsequently received for the record:]

NASA has proposed spending $235 million on development of the Earth Observing System (EOS) in FY 1991. The EOS program includes the A and B series, with three platforms in each series to be flown sequentially over a fifteen-year period. Most of the EOS work in FY 1991 will be for efforts related to the A series. The total cost of EOS through the end of this century is expected to be $17 to $20 billion. For the three A series platforms (including instruments, data systems, science analysis, and operations) for the same time period the cost is expected to be $11 to $13 billion and the similar estimate for the three B series platforms is $6 to $7 billion. The exact cost of the platforms is still unclear, as these costs depend on the exact instrument complement selected for flight, the cost of integration of those instruments, and the level of observatory flight acceptance testing.

Senator GORE. But, basically, it has only a five-year lifetime?

Dr. FISK. The design lifetime is five years. If the platform is fully working at the end of that five-year lifetime, we will not launch the second one, and may discover we do not have to build the third.

So the program has that flexibility in it. If the platform is fully working at the end of five years, we will simply have a spare on the ground ready to go when the platform needs to be replaced. And if we were to extend it for many years beyond our five-year lifetime, there would be no need to build the third platform to achieve the 15-year lifetime.

Senator GORE. Now when you talk about there being two platforms and the scientific justification for the first is compelling, and for the second it is not as compelling.

Dr. FISK. Well, it is not scientifically compelling. It may be cost and engineering compelling.

Senator GORE. I understand.

Let us focus on that first platform. How many replacements—that first platform has a five-year lifetime?

Dr. FISK. That is right.

Senator GORE. And at the end of the five years, what happens?

Dr. FISK. You put up an identical platform.

Senator GORE. That is in the budget?

Dr. FISK. That is in the budget.

Senator GORE. At the end of that five years, what happens?

Dr. FISK. You put up another identical platform, assuming you needed to replace it. And that is in the budget.

Senator GORE. And that is all that is in the budget?

Dr. FISK. That is right. Because that gives you your 15-year lifetime. The 15 years is chosen, as you know, for scientific reasons to get a number of cycles of the critical time sequences on the Earth.

Senator GORE. So you get a statistical set?

Dr. FISK. That is right. You need a certain number of El Ninos, and you need to be longer than a solar cycle. So the best science judgment was that 15 years was a reasonable time to aim for.

Senator GORE. And 15 years will begin in late 1997 or early 1998?

Dr. FISK. That is correct.

Senator GORE. Now has NASA thoroughly revamped its plans for EOS, or just slightly modified the original plans? The critics have said that when EOS was to be launched and serviced by the Shuttle, it made sense to build a large, complex platform. But, under the current circumstances, NASA should go with more, but smaller satellites.

Are there parts of the EOS program that are throwbacks to the original Shuttle-serviceable plan, which no longer makes sense?

Dr. FISK. No. There is a lot of mis-history about this. And let me share some thoughts with you on that.

When the station was originally going to provide us with a platform, they had in mind giving us a 1,500 kilogram payload. It was the science drivers for simultaneity that made this platform grow to 3,000 kilograms, not the station program. In fact, we had to convince them that they wanted to make this thing larger.

A further interesting point is when the platform was transferred over to Code E, which occurred last fall, we went through a major scrubbing of that to remove any aspect of that program which we did not need, but may have been a legacy from its station heritage. And the platform was reduced 4,000 pounds in weight and $100 million in cost.

And we are confident at the moment, that this platform is identical to what we would have designed if we had had the program from the beginning.

Senator GORE. How important will the space station be to Mission to Planet Earth? What is the most important role it will play?

Dr. FISK. The basic role of the manned space station itself is a place to bolt on some instruments that can make measurements in equatorial orbit. And we have three such instruments in the EOS program. There is a cloud and radiation environment satellite, a series instrument, which again, you get a diurnal coverage of the clouds from that orbit. We have a lightning mapper.

And what is the third?

We have a SAGE calibration. There are three small instruments that fly on the manned platform itself. But the majority of the measurements for EOS—in fact, the overwhelming majority are from the polar platforms.

Senator GORE. So the space station is not a key part of Mission to Planet Earth?

Dr. FISK. That is correct.

Senator GORE. Now, moving on to earth science. Of course, the key component of the Global Change Research Program, Mission to Planet Earth, and EOS, is in getting the data out to those who can enhance our understanding of the Earth, and changes in the global environment. As such, it is critical that the research community be in place to undertake this endeavor.

Dr. Corell, how do you see the supply of qualified Earth scientists necessary to handle this stream of data? And will the EOS program possibly contribute to the long-term objective of increasing our engineering and science talent pool?

Dr. **Corell**. The answer to your last question is I think very much so. The EOS program gives high visibility to young men and women who have a developing interest in science and engineering. The whole Global Change Research Program carries that kind of aura about it.

We are concerned that in a few years there will not be the necessary number of young men, women and minorities in the pipeline with interests in the earth sciences or science and engineering. It is a serious problem for this Nation. And NSF and the other agencies are clearly eager and willing to address that.

Within the context of the Global Change Research Program, we have established a special initiative in education and training. Within NSF's budget component, we have agreed to be the focal point for that effort, but it will be managed on behalf of the Global Change Research Program and the other agencies. It ranges from programs and efforts at the undergraduate level, right up through the post-doctoral level.

In addition, NASA has, within the EOS program, a component to support graduate studies, a special effort including fellowships. DOE has established within their component of the CES effort a major program to bring in national laboratories in the education process, and an initiative which is coordinated with the overall effort. NOAA has a similar effort.

We are going to invest in the current (FY 1991) budget, well in excess of $10 million in the first year in targeted programs, with respect to global change-related education efforts.

In addition, NSF is currently looking seriously at the pre-college aspects of this question. While I cannot assure you that it will be in the 1992 budget, I can tell you it is a very high priority within our program at NSF to address what you might call global environmental issues in the pre-college parts of SEE (Science and Engineering Education Directorate) and NSF.

Senator **Gore**. We learned long ago the importance of coordinating satellite measurements with well-distributed ground-based measurements to provide what some scientists have called ground truth. How much of the funding for Mission to Planet Earth will be devoted to ground-based measurement and research, Dr. Corell?

Dr. **Corell**. I cannot give you the percentage of the EOS program. But maybe we can supply you with those details.

[The following information was subsequently received for the record:]

Over 60 percent of the total Mission to Planet Earth, including the Earth Observing System, will be allocated to science, the Mission Operation and Data Analysis, EOS Data and Information Systems, and Ground-Based Calibration and validation efforts.

We have taken a great deal of pain during the past year, building the fiscal year 1991 program to be assured that the ground-based parts of the measurement system that are important for science are thoroughly and completely linked with the satellite program. And conversely, that satellite measurements are linked with the ground-based program. That comes about by detailed analysis in such efforts as the World Ocean Circulation Experiment, the

TOGA program, and the Global Energy and Water Experiment, GEWEX.

I do not see them as separate efforts, but as totally integrated efforts. We cannot do the science on the ground-alone. The satellites cannot do the science without the ground-based programs. This is what CES is really all about, linking those together in an integrated effort.

And I would just like to take a minute to talk to you about the Interagency Working Group on Data Management for Global Change, which we established a couple of years ago, to specifically address many of the questions you have raised here in this hearing this afternoon.

It is totally linked with EOSDIS, but it also brings together the other data management efforts of the other agencies who are component parts of the global change effort. It is fully interagency. It is totally linked with the CES process. It is a separate working group, designed to deal totally with that question.

Senator **Gore**. Who heads that working group?

Dr. **Corell**. The Chairman of that is Tom Pyke at NOAA. The Chairman of the working group is Greg Withee, who is also at NOAA. Each of the agencies in the CES is a full member of that committee.

I would like to point out that NASA has been a crucial player in the EOSDIS aspects of the work of that committee. We have done several things. Last summer we engaged in the first experiment, a prototype testing of access through the directory level of data sets. We found that the system is working. Some of the problems we are going to have to address as we move towards an integrated data system to support global change surfaced.

It is our goal to have up and running, in parallel and completely linked with EOSDIS of the NASA program, a Global Change Data System by 1994–95.

We have identified the Arctic as a region in which we can test our data management systems, using the databases that are not only in this country but elsewhere, as a prototype, to try and be sure that the ground- and satellite-based programs come together, that the access is there, that the links go back to the university systems and so on.

This working group has made major progress, and I am confident that the ground-based aspects, will be fully and totally linked with EOSDIS, which we have heard so much about here today, and that they will feed into the scientific community.

We charged that committee with a very simple task: provide the scientific community with easy access to high-quality data, obtained in all aspects of the Global Change Research Program.

Senator **Gore**. Dr. Fisk, what percentage of the Mission to Planet Earth funding will be devoted to ground-based research?

Dr. **Fisk**. In the NASA portion of the budget there is essentially none. We are not responsible for ground-based studies—unless you want Shelby to respond.

Dr. **Tilford**. I think the only part of the ground-based system that NASA is primarily responsible for is to make sure that in the initial calibration of instruments that they do the right series of either aircraft or in situ experiments to make sure we understand how the sensors work.

Senator GORE. To get your ground-based built into the calibration?

Dr. TILFORD. That is correct. The main reason is to make sure—not just the calibration. We will rely much on the other agencies in the international community for the long-term calibration. What we do need, though, is to make sure that we understand how the algorithms need to be developed.

One example is for the HIRIS and MODIS instruments we are now flying an aircraft instrument which we call AUIRIS which in terms of the number of bands and wavelength resolutions looks very much like what we will fly on the satellite.

It is very important not only that we understand what the data is and what it can be used for, but to make sure we understand how to reduce it most effectively into geophysical parameters that the scientists can use, and we have initiated that program. We have been flying the instrument on the ER-2 for about two years. We are now building up the understanding of what the data is and the algorithm techniques.

Senator GORE. If you look at the global change research program, how much of it is made up of NASA's component?

Dr. FISK. About 60 percent.

Senator GORE. About 60 percent?

Dr. TILFORD. This year.

Dr. FISK. This year.

Dr. TILFORD. Eventually it will be about 50-50.

Dr. CORELL. It is 50-50 over time. That is a good number.

Senator GORE. In fiscal year 1991, it is $661 million out of $1.034 billion?

Dr. CORELL. That is correct.

Senator GORE. Now, virtually none of that is ground-based?

Dr. FISK. No, sir, that is not quite correct.

Senator GORE. Ground-based research, I thought you just said that.

Dr. TILFORD. There is a difference between EOS and earth sciences. The earth sciences program is $661 million. Only $235 of that is EOS. There is a large and significant portion of NASA's program that is in situ. It has to do with aircraft in situ measurements and data analysis. It is over $150 million.

Senator GORE. Okay. Now, let me return to the question about existing data. How will the existing data sets be better exploited in EOSDIS?

Dr. FISK. Let me touch on that and Shelby can elaborate here. We have a number of projects underway today to improve both the access to the data, which frequently is a matter of converting data from tapes, which are unwieldy format, onto optical disks to recalibrating the data using algorithms to turn them into geophysical units.

Those projects—and there are a half a dozen or a dozen of these things, which use very important data sets, whether it is AVHRR or GOES or what have you. That data is being distributed to the science community. It will also serve as data which will be archived in the EOS data remote active archive centers. These racks will get this appropriate amount of data.

Senator GORE. Wait a second. Let me ask you to pause there for a minute. You said just a moment ago in reference to GOES, for example, that that data is being distributed to scientists?

Dr. FISK. It will be as we make this conversion.

Senator GORE. But it is not now?

Dr. FISK. It is not now. The agreements with NOAA have just been struck.

Senator GORE. How recently?

Dr. TILFORD. Within the last month.

Dr. FISK. Within the last month.

Senator GORE. Within the last month?

Dr. FISK. That is correct. I should compliment very much here the new director of NOAA, Dr. Knauss, who has taken a very positive, enlightened attitude on this activity and has made this possible.

Senator GORE. I have had an extensive dialogue with him on this question as I have with you, and I am very pleased that you all are working this out, but just to take GOES as a specific example, when do you expect the data to be transferred to optical disk?

Dr. TILFORD. We would expect to start next year. We are right now involved in a pilot with the University of Wisconsin, which is the NOAA contractor for currently storing the NOAA GOES data on, essentially, videotapes. They are digital, but nevertheless, that is the mode that Verne Suomi devised which I think was unique ten years ago.

You have to give Verne a lot of credit for having the data to where we can even get to it today, but the point is there is no browse capability. It is very difficult to go in and find out what data is there and how you get to it.

Senator GORE. So you are doing a pilot project, and then you expect in the next calendar year, what?

Dr. TILFORD. This is a very large data set and we do not have any hardware on board. We expect it will take a minimum of five years to transpose all of those.

Senator GORE. Five years to transfer it from videotape to optical disk?

Dr. TILFORD. That is about the time scale. If we had a lot more up-front money we could do it a lot faster.

Senator GORE. How much data is in the GOES data set?

Dr. TILFORD. I believe—and I am sure to get this wrong by a zero, but I believe it is 10 gigabytes, and I will check on that. I should have that answer at my finger tip.

Senator GORE. There is essentially no practical way to exploit it until it is transferred to optical disk?

Dr. TILFORD. With the existing storage capability and the way that the data has been used, we are utilizing the data now in terms of the international cloud climatology program that Dr. Baker mentioned earlier, so this image data is converted.

It is taken up and it is all compiled with the other geostationary data at GIS. It is processed there, and then data products in terms of cloud top heights, cloud top pressures, total clouds percentagewise, surface temperatures, radiance and a number of other parameters, that is being done now. But in terms of going in and utilizing the GOES data as an active archive, it is virtually impossible the way the data is currently done.

Senator **Gore**. Now, the project to transfer the GOES data from videotape to optical disk is expected to take five years. How much is it expected to cost?

Dr. **Tilford**. I wish I could give you an exact answer for that.

Senator **Gore**. You can provide that for the record.

Dr. **Tilford**. We will give you our current estimate. As we proceed through the pile we will have a much better handle on that.

[The following information was subsequently received for the record:]

The National Oceanic and Atmospheric Administration [NOAA] is responsible for funding this activity. NOAA has requested as much as $10 million for this purpose in recent years.

Senator **Gore**. Whose budget does that show up in?

Dr. **Tilford**. Currently the proposition is that NASA will be responsible as part of the preliminary EOSDIS for doing most of this. We have struck an agreement for the pilot study and it will be equally contributed to or funded by both NASA and NOAA. We would very much like to see that arrangement continue in the future.

Senator **Gore**. What about LANDSAT?

Dr. **Fisk**. The case of LANDSAT is a very simple issue. It is that the data, under current pricing policies, is too expensive to use for research purposes.

Senator **Gore**. We have collected it and we have put in place rules that make it impossible to use it?

Dr. **Fisk**. That is absolutely correct.

Senator **Gore**. It is sort of like our agricultural policy. We have silos with grain, with massive starvation.

Dr. **Fisk**. Let me tell you how it is arrived at, but I think it is indicative at least. I asked someone the other day to do a calculation of what it would cost to buy a LANDSAT image of the entire earth. After all, we are interested in global chance.

Senator **Gore**. 15,000 CD ROMS. We ran that one out, too.

Dr. **Fisk**. It turned out to be $50 million at current pricing policies—one image of the earth—and since we are interested in global change we would want to see this time and time again. That is why the data is prohibitively expensive.

Senator **Gore**. We are going to have the first LANDSAT image of the entire earth, incidentally, at this conference, the Interparliamentary Conference on the Global Environment at the end of April.

Dr. **Fisk**. Who paid for it?

Senator **Gore**. We are getting it for free. I think it was private.

Dr. **Corell**. Well, I know of two agencies——

Senator **Gore**. You know of two agencies that did not. Right. I think this is a commercial venture that hopes to recoup costs by selling the image.

So your exploitation of LANDSAT data awaits resolution of that pricing formula?

Dr. **Fisk**. That is correct.

Senator GORE. How can that be resolved?

Dr. FISK. I think you have to—I am not sure. It is a combination of the legislation but it is also—I mean, this is a choice of the commercial venture as to what those pricing policies are, am I correct?

Dr. TILFORD. This is an extremely complex and not simple issue, as you are perfectly aware.

Senator GORE. We are going to have a separate hearing on this, and maybe it is best just to wait until then, rather than getting into it now, but if you have a 30-second overview we will hear it.

Dr. TILFORD. Well, I would like to make some comments, and briefly. One is, we believe that if the global change program is ever successful, certainly we have to look at how researchers have access to the data, in a different mode than currently exists with existing legislation.

That does not mean that commercialization for commercial purposes is not viable, nor important. However, in order to do the kind of analyses that we believe are necessary, we think the minimum that is required is a two-tier approach in terms of providing data to people who are willing to turn their products back into the public domain versus those who are not.

Senator GORE. Say that again, please? A two-tier approach with a cheaper rate for those who are willing to put it back into the public domain?

Dr. TILFORD. Exactly.

Senator GORE. Well you recommend a legislative initiative by us to fix this pressing problem, do you?

Dr. TILFORD. I do not know of any other way of doing it, sir.

Senator GORE. So that is a yes?

Dr. FISK. Yes.

Senator GORE. Okay. We have already begun to look at that and we will be proceeding with a recommendation. Of course, that has to be done at the full Committee level. That is a decision that others will have to shape. I will certainly be giving my recommendations on it.

What is the volume of data, Dr. Tilford, in the LANDSAT archive if there are ten gigabytes, roughly, give or take a zero, in the GOES program? How would you quantify it?

Dr. TILFORD. There is approximately at least an order of magnitude more, if my ten gigabytes number is correct.

Dr. FISK. We have one Tilford here scaling this.

Dr. TILFORD. I will get you those numbers.

[The following information was subsequently received for the record:]

There are two primary locations for archiving land remote sensing data in the U.S. The U.S. Geological Survey (USGS) operates the EROS Data Center in Sioux Falls, SD as the primary archive for non-commercial land remote sensing data. Approximately 36 terabytes of data are archived in this facility, including data from early Landsat missions, from the Multispectral Scanner (MSS) instrument aboard Landsat, from the Advanced High Resolution Radiometer (AVHRR), and from other sources (Return Beam Video). The other primary archive is the Earth Observation Satellite Corporation (EOSAT) in Lanham, MD. Approximately 125,000 scenes of thematic mapper (TM) data from Landsat, totaling 36 terabytes, constitute this archive.

The Solar Backscatter Ultraviolet (SBUV) instruments collected 50 gigabytes of Level 1 data and 6.5 gigabytes of higher level data through 1988. The Total Ozone Mapping Spectrometer (TOMS) instrument aboard Nimbus-7 has collected 40 gigabytes of Level 1 data and 18.5 gigabytes of higher level data since deployment in 1978. The inflow of data from this TOMS instrument is about 5 gigabytes per year. The total archive of SBUV/TOMS data (located at the National Space Science Data Center at GSFC) is approximately 115 gigabytes.

Senator **Gore**. We could come up with a new unit of measurement, then—one Tilford.

Dr. **Fisk**. That equals GOES.

Dr. **Corell**. Yes, that equals the GOES data set. Ten Tilfords gives you LANDSAT.

Dr. **Tilford**. It may be 100 Tilfords.

Dr. **Corell**. I do not know if we can handle that.

Senator **Gore**. Now, how would you quantify—what estimate do you have of the amount of data in five years of EOS? How many gigabytes?

Dr. **Fisk**. It is ten terabytes per day.

Senator **Gore**. Ten terabytes per day.

Dr. **Fisk**. So I suppose in five years that is 1,800 times ten, so it's 18,000 terabytes.

Senator **Gore**. It's 18,000 terabytes.

Now, is it fair to say that even though the volume of data collected by EOS is so much larger than the amount that has been collected as to defy the imagination, the value of the EOS collected data can become greatly enhanced by algorithms relating its significance to previously collected data which can give reference to earlier decades.

Dr. **Fisk**. Yes, that is certainly true.

Senator **Gore**. Take the TIROS-N data sat that we discussed earlier.

If there were some way to compare that data to corresponding snapshots of earlier decades, its usefulness might be greatly enhanced.

If, according to the same logic, we collect a vast quantity of data for five, ten, or 15 years, ending in the next century, the usefulness of the first five years' data and the second five years worth of data can be greatly enhanced if we can somehow compare it to reference points that were collected 20, 30, or 40 years earlier.

Dr. **Fisk**. Senator, that is quite correct. Whenever you are looking for things that are as subtle as global change, long-time data sets are the key. That is why EOS runs for 15 years. But if we can go back and find anchor points for that data to see, clearly, they will be snapshots, they will not be at the same resolution, and so on, but they will be indicative of what changes are occurring.

Senator **Gore**. Okay. Now, going back to the archive data—we've talked about GOES, we've talked about LANDSAT—would those be your first two priorities, assuming you could unlock the access to LANDSAT?

Dr. **Fisk**. Well, I think AVHRR data.

Dr. **Tilford**. That's number one.

Dr. **Fisk**. Yes, AVHRR.

Senator **Gore**. That's number one. How many gigabytes in that data set.

Dr. **Fisk**. One.

Senator **Gore**. Over what period of time?

Dr. **Tilford**. It is TIROS-N data. So it exists for the same time.

Senator GORE. From 1979.

Is it digital?

Dr. TILFORD. Yes.

Senator GORE. It doesn't have to be formatted differently?

Dr. TILFORD. Yes.

Dr. FISK. The intent is to put it on DIS beginning in 1991 and finish by 1994.

Senator GORE. Why would it take that long?

Dr. TILFORD. Again, we are starting from zero. That means we have to go out and procure the equipment, buy the equipment, do the algorithms. The first three years are the slow pieces. Once we have full-up operation, we would hope to reach steady-state in about four years.

Dr. FISK. I think, Senator, there is one thing that is important. There is a lesson in this, that we must never allow ourselves to fall behind on the EOS data analysis as it comes down.

Dr. TILFORD. Right. And, of course, when we talk about——

Senator GORE. And how many terabytes are in that one, or how many dodecabytes, or whatever it is.

Dr. FISK. Yes.

All of our efforts in developing the EOS data system early are to insure that it is simply an operational system, that within 24 to 48 to 96 hours after the receipt of that data, it is adequately stored and distributable.

Senator GORE. If the AVHRR is your number one archive data set, what is your number two?

Dr. TILFORD. Let me say that we do have two or three data sets that are now archived. One is the solar constant measurement, which we felt was necessary.

Senator GORE. Right. Optical disk?

Dr. TILFORD. No, it's on tape. But there are not very many bits of data here. So that is a mute issue.

Senator Gore. "Moot" as well as "mute," I would say, if we don't have access to it.

Dr. TILFORD. No, we have access to it. It is in NSSDC at Goddard. Anyone can have access to that data who wants it.

Senator GORE. And so, the ability to browse is not an issue?

Dr. TILFORD. That is not an issue here because we are talking simply about a few bits per minute over a period of ten years. That is not anything it can't handle.

Dr. CORELL. It's a CD ROM problem.

Dr. TILFORD. One-third of a CD ROM problem.

Dr. CORELL. One CD ROM does the whole thing.

Senator GORE. One "micro-Tilford."

Dr. CORELL. Yes, one "micro-Tilford.

Dr. TILFORD. The next one, of course, is the CZCS data which we now have archived to optical disk, and we have essentially a browse file on three optical disks that we can mail to anyone in the world and they can look at it.

Senator GORE. How much data is in that?

Dr. TILFORD. It's about a terabyte, also.

Senator GORE. Okay.

Next?

Dr. Tilford. The next one which we feel is extremely important is the long-term ozone trend data, and that is data from SBUV and TOMS. That exists for ten years. Again, that is only a few optical disks.

Senator Gore. It's already on optical disk?

Dr. Tilford. It is being processed to optical disk. Right now we have it on digital tape and on video film.

Senator Gore. How many bytes?

Dr. Tilford. I'll have to get you that for the record.

Senator Gore. Yes, provide that for the record.

When do you expect to have it converted to optical disk?

Dr. Tilford. I will get you that answer, also.

Senator Gore. All right.

Next?

Dr. Tilford. It doesn't take long to do that.

The next priority data set on a global basis I believe will be the TIROS-N temperature sounding data. That requires reprocessing. It is less than the AVHRR data.

The algorithm is somewhat more complex in the sense that we have to, right now, do significant man-interactive reduction. So it is going to be somewhat slower in that it is not completely automatic. We hope to do that in a few years.

We would also hope to have that available before 1994 and 1995 at the latest.

Senator Gore. All right. What's next?

Dr. Tilford. Finally is the GOES data. Then is LANDSAT, LANDSAT being much more complex.

Senator Gore. Any others?

Dr. Tilford. I personally do not know of another global data set that we have access to at the present time.

Senator Gore. Now, all of the ones you have mentioned are satellite data sets.

Dr. Tilford. They are also global data sets.

Senator Gore. They are also global data sets.

Who is in charge of mining other archive data sets?

Dr. Tilford. That is a function of the IWG, the Interagency Working Group, that Dr. Corell discussed earlier. We are working that issue right now in real time.

Senator Gore. Dr. Corell, what are your top priorities in nonsatellite data sets?

Dr. Corell. Senator, I'll have to give you a report on that. I don't have it at my finger tips.

In answering your question, I would like to note that non-satellite data sets are of interest for two reasons—first, they calibrate and validate satellite signals, and second, for earth variables not capable of measurement from satellites, such non-satellite measurements are the only source of data. The Earth System Science Committee (ESSC) and later the National Academy of Sciences Committee on Global Change have given some insight as to the priority of non-satelite or *in situ* data sets. The absolute priority is not available, and in fact the priority will change with time as we learn more about the earth system. However, some of the more important variables, taking into account both considerations as mentioned above, are listed in the following table.

[The table follows:]

KEY GLOBAL CHANGE ENVIRONMENTAL VARIABLES REQUIRING NON-SATELLITE MEASUREMENTS

RADIATIVELY OR CHEMICALLY IMPORTANT TRACE SPECIES

Carbon Dioxide
Nitrous Oxide
Methane
Chlorofluoromethane
Tropospheric Ozones
Carbon Monoxide
Stratospheric Ozone
Stratospheric Aerosols

ATMOSPHERE

Surface Air Temperature
Tropospheric Temperature
Stratospheric Temperature
Surface Pressure
Tropical Winds
Tropospheric Water Vapor
Precipitation
Earth Radiation
Cloud amount, type, height

LAND SURFACE

Index of Land Use Changes
Index of Vegetation Center
Soil Moisture
Biome Extent Productivity and Nutrient Cycling
Topography
Lithology and Mineral Composition
Streamflow
Ground Water Level

OCEAN

Sea Surface Temperature
Sea-Ice Extent
Wind Stress
Sea Level
Subsurface Circulation
Ocean Chlorophyll
Biogeochemical Fluxes
Ocean CO_2

GEOPHYSICAL

Plate Motions
Plate Deformations
Gravity and Geoid
Global Seismic Properties

PALEOCLIMATE

Atmospheric Composition
Land and Ocean Temperature
Vegetation
Ice Volume and Extent

Senator GORE. How many are there, roughly?

Dr. CORELL. The Interagency Working Group, through its Master Global Change Directory, has already accounted for about 500 non-satellite data sets but there are many more to be cataloged. This number will eventually range into the tens of thousands. It is much larger than the number of variables given in the above table primarily because many data sets exist for each variable. However, very few long time global data sets exist, and in part, much of the data management resources requested by agencies in FY 91 will go toward assembling global data sets for use in global change studies.

Senator **Gore**. What about regional data sets?

Dr. Corell.

Regional data sets can also be of value if they are deemed representative of global change or are in sensitive areas, and if taken over a long period of time.

Senator **Gore**. You are looking at those, too?

Dr. **Corell**. Absolutely.

Senator **Gore**. If you could, supply that for the record as soon as possible, along with how much data, how many bytes or whatever of data is in each set, your time estimate for how long it would take to convert each to optical disk with a cost estimate, and whose budget you assume each of these tasks will appear in.

[The following information was subsequently received for the record:]

A summary of non-satellite data sets can be found in the following table. Note that this list does not include data sets from the human interactions element of the Global Research Program. These requirements need to be developed. Also please accept these estimates as rough order of magnitude only. In order to get more accurate costs, an individual assessment would have to be made as to the state of each data set within each category.

CONVERSION TO OPTICAL DISK

[In millions of dollars]

Nonsatellite data set categories	Size (GB)	Time (years)	Resources	Agency
Trace Species	<1	1	$1.0	DOE, EPA, NOAA, NSF.
Atmosphere	1,000	20	40.0	DOD, NASA, NOAA, NSF.
Land Surface	150	10	10.0	DOE, DOI, EPA, NASA, NOAA, NSF, USDA.
Ocean	100	10	10.0	DOD, EPA, NASA, NOAA, NSF.
Geophysical	50	5	10.0	DOI, NASA, NOAA, NSF.
Paleoclimate	10	5	2.0	DOE, DOI, NOAA, NSF.

Now, let's fast-forward to a time when we have lots of these archive data sets on optical disk, we're able to look at them, and we're able to analyze them.

What is the relationship between this data and the EOSDIS system?

Dr. **Fisk**. In the case of EOSDIS, it sort of comes, as you know, in two parts. There is the part to command the satellite and get the data down from the satellite. That we do not need until 1997, when we are actually going to command the satellite.

It also, however, includes not only these remote archiving, active archiving systems, which will include these new data sets or the reworked data sets, re-mined data sets, it includes distribution systems, it includes computer facilities at our interdisciplinary teams and at the other principal investigator institutions and scientists who are involved in the EOS project.

So, if you sort of had a chart in your head that started with the EOS satellites and the TDRSS on the top, and then down through the remote archiving systems and down to the actual individual computer facilities that are down at the bottom of it, what comes on line in the 1993-94 timeframe is the bottom half of that chart. It is the ability to distribute data and analyze data at researchers' institutes and essentially play with—and I do not mean that in a derogatory sense—play with this data that is available, plus the data from the 19 missions that have come, and develop the techniques for making this distribution easy.

Senator GORE. Okay.

Now, it's 1994 and we have virtually all of the data sets we have discussed here on optical disk, and most of yours, too.

Dr. CORELL. That's the critical time that we are all driving for—1994-95.

Senator GORE. All right. Now where it is stored?

Dr. FISK. It depends on which data set it is.

Senator GORE. Different places?

Dr. FISK. Different places. The trick, of course, to be successful in distribution, is there exist master directories and easy systems for accessing that data. Whether it is a uniform form, and I mean electronic form--you know, to tie up, you dial into your telephone and a little thing says this is where the data is and this is how you get it, punch button X and the data somehow comes to you, whether it comes over the lines themselves or whether in the case of certain imaging data, it may be a whole lot easier to send an optical disk through the mail.

Senator GORE. Will it be one of those seven archive centers?

Dr. TILFORD. For the EOSDIS, it will be one of probably seven, plus or minus two.

But, tied into this will also be the archive systems that Dr. Corell talked about that are being developed in terms of ground-based systems.

But if you mean satellite data, yes. If you mean the total data system, it will be much more distributed than those seven centers.

Senator GORE. All of the satellite data sets that we discussed will be in one of the seven places?

Dr. FISK. That's correct.

Senator GORE. Why wouldn't the ground-based data sets be in that, too?

Dr. CORELL. Some of them might. Others will exist in centers like NCAR, where we have a classic evolution of atmospheric data that will be linked through the directory system.

Senator GORE. We talked about a common format.

Dr. CORELL. Yes, they will be consistent.

Senator GORE. They will all have a common format?

Dr. CORELL. Well, you know, there are new techniques evolving. Some refer to "enveloping." It is not too different from sending things in the mail. You put electronic envelopes around them. While this particular data set might not be in exactly the same format as that one, you have the instructions in the envelope to decode them and be able to use them.

The techniques that we're planning to use are based on the so-called "village approach," where you have a number of villages, but they are all connected and interlinked, so that you ultimately have a massive data system.

It looks like a big data system, but it is still distributed.

Senator GORE. We passed this morning, in the full Committee, S. 1067 the data super highway network bill. One assumes that will be helpful in this area.

Dr. CORELL. Extraordinarily so, sir.

Dr. TILFORD. I think if you could visualize this, it is very much like TeleMail today, where if you happen to have a MacIntosh or an IBM or whatever computer, the formats aren't the same inside the computer, but it is transparent when you dial up to a central computer that you can exchange information with different formats; but it all looks the same when it comes out on the screen, or the disk.

Senator GORE. Now, will the ground based data sets be a part of EOSDIS, even though they are not in the seven centers?

Dr. FISK. They will be accessible.

What you really want to do is get this data out to researchers and universities so that they can access our seven archive centers for the satellite data, and they can access the NSF centers. The idea is to make it easy, the TeleMail approach here, to be able to dial up and get data from where you need it.

Senator GORE. Yes. But just as Mission to Plant Earth exists in NASA and then, in a slightly fuzzier way, in a larger context as well, it seems to me that we are headed toward a data system that exists in NASA and then in a larger context as well.

Is that going to pose problems?

Dr. CORELL. I don't think so.

Senator, when a scientist decides he wants to browse the directories to come up with a data set that happens to be important, he isn't going to have the slightest idea where that data is. It's just like when you pick up and use your TeleMail, you don't know where the computer is that houses the mailboxes and the protocols that operate the system.

We would like to have these be transparent to the user. When he is doing science or she is doing science, whether it is in the Midwest, the Northeast, or, for that matter, in Europe, we would like to make that as transparent as possible. Those are the goals of the data system.

Dr. FISK. You may recall in the panel discussion previously, one of the strong recommendations was for a highly distributed data system. You know, centralization is not something that people recommend in this business and we concur in that recommendation.

Senator GORE. Right.

Let me ask you this question.

We are collecting LANDSAT data right now, even as we speak here.

Does it make sense to begin immediately collecting LANDSAT data on optical disk, as it comes down, or does it make sense to continue collecting it in the current format and then go back several years later and translate it on to optical disk?

Dr. TILFORD. I think you have to look at this in two different ways.

To be very pragmatic, I think it would probably be somewhat foolish to start collecting it on optical disk today.

I think, after we arrive at some formats in the way that we represent data in four dimensions—X, Y, Z, and T—that are internationally agreed to, perhaps in the next two years, then it would make sense to start collecting data in that mode.

Senator GORE. I have to believe there might be some usefulness in analyzing an intermediate data format.

Dr. TILFORD. I do not disagree with you. But right now, within Canada and Europe and the United States, there are different ways that data is gridded. If you want to use this data for global change, it would be a whole lot cheaper just to reprocess it all one time than two times.

Senator GORE. If you want to supplement that response for the record, I would welcome a brief analysis of the question. My question may be hopelessly uninformed, but I am working on the assumption that there is a possibility the analytical work necessary to transfer it from its current format to what you need may be significantly more difficult than might be the case if you collected it as it arrives in some intermediate format that made it easier to convert it.

Dr. TILFORD. As you are probably aware, EOSAT now provides quarter image capabilities on optical disk. So the main thing is LANDSAT was designed to bring data down to a certain kind of processing and put it on a certain kind of tape.

That processing probably would be so expensive to reconfigure right now to an optical disk storage media that it probably would cost much more in the long run.

I would be happy to sit down with EOSAT and USGS, Senator, and work something out for you on that.

Senator GORE. For the record, if you could expand on the definition of "probably," it would help us.

Dr. TILFORD. And I hope I would have a few weeks to do this.

Senator GORE. Oh, absolutely. Absolutely.

I have a number of other questions for the record. We have run over the time that we had to finish up the hearing. So I will ask my other questions for the record, if that is all right.

Let me conclude by saying that I am very impressed with the amount of work that has gone into this program. I want to express my gratitude again for the work that has been done in the last few months on addressing this question of how to deal with existing data sets. You have obviously done a great deal of analysis on it. A lot was done well before this Subcommittee ever started asking the questions; but a good deal has been done since that time as well, and I am grateful for that.

I really think you have done a very good job on this program.

I am impressed that the Committee approach may well have utility in easing the normal turf battles that you could expect in an enterprise like this. I do wish to return at later hearings to this question of management structure, because I think Dr. Eddy and others have gently formed the question of how a new phase of the program might tax the current decision-making structure—not to reflect at all on the individuals who are part of that structure, but just to raise the question of whether or not we might need to have a little more focus than the Committee structure now provides.

I have an open mind on that question. I hope that the Committee's persistence in asking the question helps in itself to highlight the significance of the Committee filling in what might be a natural weakness in structure. We are going to be looking very carefully in the months ahead at whether or not that problem does appear.

I will look forward to the supplementary answers you have promised for the record and will be returning to look at this in some detail in several hearings throughout the year.

With that, I appreciate all of you coming and we will stand adjourned.

[Whereupon, at 5:25 p.m., the Subcommittee adjourned.]

AERONAUTICS AND SPACE TECHNOLOGY

THURSDAY, MAY 3, 1990

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The Subcommittee met, pursuant to notice, at 9:30 a.m., in room SR-253, Russell Senate Office Building, Hon. Albert Gore, Jr., (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. Good morning, ladies and gentlemen. I am pleased to call to order the Subcommittee's hearing on the fiscal year 1991 budget request for NASA's Office of Aeronautics and Space Technology.

As we will hear shortly, NASA is engaged in a wide range of research and development efforts critical to aviation and space, including work on future aircraft technologies, the national aerospace plane, space research and technology and space exploration. The type of basic and applied research and technology development conducted by NASA is essential for the future competitiveness of the U.S. aerospace industry, which in turn will help preserve our position of leadership in aviation and space.

In addition to our review of NASA's budget and related policy issues, this will also be our first formal opportunity to examine the President's proposal for manned exploration of the Moon and Mars. We are fortunate to have a distinguished panel of witnesses to assist us in this review, as there are a variety of major issues that must be addressed before this country can begin to address such a massive undertaking.

Aerospace is now this country's leading trade surplus industry with nearly $27 billion in exports in 1988. Few can therefore question the need for NASA's work on emerging technologies as essential in retaining and enhancing that leadership position. In that regard, NASA's recent research and development work on aircraft structures and engines has proven a key reason that U.S. commercial aircraft manufacturers are now enjoying record purchase orders from abroad.

Of course, nothing comes easy. There are serious issues that lay ahead of us. Take, for example, the future development of high speed commercial aircraft which will be capable of traveling at speeds in the neighborhood of Mach 3. With one eye on foreign competitors, U.S. manufacturers are now working on a number of major economic concerns related to the financial viability of these next generation aircraft, but serious attention must also be devoted to related environmental issues, most importantly, ozone depletion, and of course, noise. NASA's research work into these areas is of vital importance not only to the future of the high speed transport aircraft, but the future of the environment as well. In this regard, I am pleased NASA has made this a priority in the current budget request.

Shifting to space, the President's proposal for the U.S. to return men to the Moon and to Mars has generated a great deal of interest and debate. In my opinion, that debate is good, for the pros and cons of the Moon/Mars mission must be fully aired before we can proceed. But I must say at the outset that I have serious concerns about the viability of the program as it is presently proposed.

In fiscal year 1991, a relatively small amount of money—roughly $190 million—has been requested to begin the development of technology needed to support the Moon-Mars mission. But that small amount is projected to increase to more than $1 billion in fiscal year 1995. Before all is said and done, some expect the current proposal for human exploration of the Moon and Mars to cost the U.S. taxpayers $500 billion.

Let me say that President Bush deserves enormous credit, in my opinion, for initiating an increase in fiscal year 1991 funding for NASA of 23 percent. However, I need not remind anyone in this audience that the Federal Government is functioning under the fiscal constraints of Gramm-Rudman. As a result, NASA is not likely to see such a significant increase—in fact borne out by recent actions taken in the House and Senate budget Committees to cut the $15.1 billion request by roughly $1 billion.

There strong support for Space Station Freedom, for the Space Shuttle program, and for the other new start in this year's NASA budget, the Earth Observing System. Given very real fiscal constraints, I therefore have deep concerns that the Moon/Mars mission might over-extend the space program and hinder our ability to adequately fund these other programs. Above all, we cannot get into a situation that would require cannibalizing existing programs to support one that has yet to be fully defined.

I have an opening statement that Senator Hollings would like to have included in the record.

[The statement follows:]

OPENING STATEMENT BY THE CHAIRMAN

Today's hearing focuses on a critical element of NASA's mission, research and development programs designed to support the U.S. aeronautics and space technology program. NASA's activities are crucial to our Nation's ability to compete in the worldwide technology market.

In this regard, President Bush and Vice President Quayle convened a meeting earlier this week with congressional leaders to discuss the future direction of the U.S. space program, focusing on the 23 percent funding increase proposed for the coming fiscal year for NASA. This "Space Summit" was organized to provide an opportunity for the President to highlight the importance of the space program to the United States. As one who has worked with NASA and the astronaut corps since the early days of Apollo in the 1960's, and who has long been a strong supporter of the exploration of space, I for one, am familiar with the contribution that the space program makes.

However, in my mind the real reason for the Space Summit was to shore up support for the President's proposal to send U.S. astronauts back to the Moon, and then, on to Mars. The Space Exploration Initiative (SEI), as it is now being touted, is the President's $500 billion plan for technology development and space exploration in the 21st Century. While the President deserves credit for establishing space goals for all Americans, the fact is, however, that without help from the Administration in making difficult decisions on establishing funding priorities—both with the space program and throughout the Federal government—there will be no mission to the Moon or Mars in the Fiscal Year 1991 budget.

Some 98 percent of NASA's budget request for FY 1991 is dedicated to on-going programs—the Space Station Freedom, the Shuttle, the Great Observatories, the Advanced Solid Rocket Motor program, to name a few. And there is very strong support in the Congress for the proposed new start for NASA in FY 1991, the Earth Observing System, which is a part of our Mission to Planet Earth and the U.S. Global Change Research Program. Without the leadership of the President—particularly in identifying new sources of revenue—even funding of these programs at the levels needed to sustain critical program activities will be difficult. Furthermore, without that leadership, NASA will not be given the go ahead on the proposed Moon/Mars mission.

We all agree that NASA's work on future technologies is critical to the future competitiveness of the U.S. in the world aerospace market. In aviation—both commercial and military—NASA's research and development work has ensured our continued superiority. In space, NASA's basic and applied research, and its technology development programs have helped ensure countless successful missions. It is therefore essential that work proceed on the research and development of critical technologies. At the same time, however, funds are limited and, as such, NASA's research and technology effort must be focused on well-defined missions. We must ensure that existing initiatives are adequately funded, and that if new initiatives, such as the $500 billion SEI are to be funded, the Administration works with Congress to find additional funding sources.

Senator GORE. Now, we have four witnesses this morning. First of all, we will hear from Aronld Aldrich, Associate Administrator of the Office of Aeronautics and Space Technology with NASA, and you are accompanied by two assistants. Mr. Aldrich, I will ask you to introduce them in a moment. We will then have a panel on the human exploration initiative, Lieutenant General Tom Stafford, Dr. John Logsdon and Mr. James Harrington. We will take that testimony after our first witness.

Welcome, Mr. Aldrich. We are delighted to have you here and look forward to your statement. Please introduce your colleagues and we will get started here.

STATEMENT OF ARNOLD D. ALDRICH, ASSOCIATE ADMINISTRATOR, OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY, NASA; ACCOMPANIED BY DR. ROBERT ROSEN, DEPUTY ASSOCIATE ADMINISTRATOR; AND MARK CRAIG, SPECIAL ASSISTANT FOR EXPLORATION

Mr. ALDRICH. Thank you, Mr. Chairman. I am delighted to be here this morning, and I would like to submit my prepared statement for the record and briefly summarize the content of our program for this fiscal year.

Before I start, though, I would like to introduce Dr. Bob Rosen, deputy associate administrator, and Mr. Mark Craig, my special assistant for exploration, who are both here with me today.

The overall goal of my office is to ensure continued U.S. world leadership in aeronautics and space through advances in technology. Congress has long recognized the importance of this goal, and has recently declared that preeminence in space and aeronautics is key to the national security and economic well-being of the United States.

Developing advanced technologies is essential to maintain our preeminence, and I am pleased here to present our fiscal 1991 budget request, which reflects NASA's strong commitment to that goal: $512 million for aeronautics, $119 million for trans-atmospheric research and technology, $496 million for space technology, and $37 million for exploration mission studies.

This month marks the 75th Anniversary of the founding of NASA's predecessor, the National Advisory Committee for Aeronautics, and the birth of this Nation's commitment to preeminence in aviation. Since the establishment of NACA in 1915, our aeronautics program has provided an extensive technological resource within the United States which has contributed broadly to U.S. leadership in both civil and military aviation.

Today, our aeronautical products provide the largest positive contribution to our balance of trade of any commercial area, and enhance the transportation infrastructure and the national defense required for long-term well-being of the United States. However, although we remain the world leader in aviation, we as a Nation are being challenged—challenged by strong foreign competition and by increasing demands on our national air space system. In response to these challenges, NASA has formulated a strong program to address overall national needs in aeronautics, and I would like to cover just a few highlights at this time.

We are significantly increasing our research efforts to resolve the critical environmental issues associated with supersonic air transportation—the next plateau of competition in the international aviation arena. The areas being addressed are atmospheric degradation, airport noise and sonic boom.

We are also moving aggressively forward in advanced composite materials and structures to provide improvements in aircraft performance through reduced structural weight, and we are strengthening our cooperation with the Federal Aviation Administration to develop long-term solutions to a wide variety of aviation safety, aging aircraft and traffic congestion issues.

NASA continues to pioneer the development of a broad knowledge base to extend our aviation preeminence in the future. We continue to develop and exploit the most advanced computational systems for application to the design and analysis of aerospace vehicles. In this regard, we have increased our emphasis on high performance, highly parallel computers, and we continue to work actively with other members of the Government's high computing initiative team to define and implement a national program in this area.

NASA remains committed to developing, operating and maintaining critical national facilities for aeronautical research to support industry, DOD and NASA programs. We have included in this request the third increment of our five-year major internal revitalization program which began in 1989. In addition, we requested an augmentation for facility maintenance to assure that continued operational capability and productivity.

True to our historic role of developing technologies for U.S. preeminence, NASA is pursuing development of revolutionary new technologies to provide options for the next generation of aerospace vehicles. The National Aero-Space Plane is a joint NASA-DOD program which combines aeronautics and space technology and which will dramatically change perceptions of time, distance and access to space.

Its goal is to develop a reusable, air-breathing hypersonic transatmospheric vehicle capable of horizontal take-off from conventional runways and obtaining orbit in a single stage. Our budget for the National Aero-Space Plane is fully consistent with the national commitment and rephasing recommended by the National Space Council and approved by the President last summer.

NASP is the most technically challenging aircraft program in the world, and we believe it is essential to our aerospace future. Technology is an essential element of investing in the future, a message that the President sent to Congress along with this budget request.

Our Space Research and Technology program contributes significantly to space missions by increasing mission safety and reliability, reducing development and operations cost and enhancing mission performance and benefit. It also has significant national benefit beyond the NASA space program. It enhances U.S. aerospace competitiveness and builds strong partnerships with industry and the university community. It provides both stimulus and support to the education of the next generation of American engineers and scientists.

Most importantly, advancements in technology have made possible the many past and current achievements of the civil space program. The Space Technology budget is a balanced technology effort which consists of four major elements. Our research and technology base, the civil space technology initiative, the in-space technology experiments program, and now the exploration technology program. The content of these elements in this year's budget request will enable us to continue to build and expand the capability for Space Station Freedom, to enhance the safety, reliability and performance of our current and future space transportation systems, develop enhanced capability for future space science missions, improve our ability to operate in space effectively, and invest in the critical technologies required for the human exploration initiative.

As you know, the President has proposed a new vision of space exploration based on a long-term continuing commitment beginning with the completion of Space Station Freedom, then journeying back to the Moon, this time to stay, and finally followed by a manned mission to Mars.

My new organization, the Office of Aeronautics Exploration and Technology, was established to enable two closely-related human exploration initiative tasks—the definition of mission concepts and an intensive development of related new technologies—to be fully integrated to benefit from a single NASA management focus.

In addressing the human exploration initiative itself, I would like to point out that the President provided a very clear focus of where we are heading, but I must emphasize that while considerable analysis has taken place, a great deal of work remains before a detailed program plan for missions to the Moon and to Mars can be formulated.

Today, we must begin essential work so that we can understand technically what needs to be done. This will enable us to develop a program plan with a variety of options over the next several years for consideration by the President and by Congress. Part of our effort will be an outreach program which will tap the best of America's creativity for new and innovative ideas, mission strategies and technologies.

One of the most important questions we have asked ourselves at the outset is why we are doing this. What drives us back to the Moon and then on to Mars? Instead of one answer, I would suggest that there are a number of psychological, philosophical, scientific and economic reasons to proceed in the manner outlined by President Bush.

There is a human imperative to explore and to reach out to the stars. There is an opportunity to gain profound insight about the nature of life and its place in the Universe. There is a need to move out into the Solar System, to better understand our own planet's origin, evolution and global dynamics. For the near-term, we need to improve our competitive posture in our country, and this space initiative will pursue technologies which will strengthen our educational system and our industrial base in a way few other activities can. Finally, this initiative will continue our countries journey into space, a journey that has already brought numerous benefits to the Nation.

Over the next several years, we need to invest in a wide range of technologies to support and then enable this initiative. We need to be able to ensure the safety and productivity of humans, which means understanding life science issues, and developing systems to sustain crews for long periods of time in space, and we need a better understanding of the possible range of mission strategies we can employ.

I believe we should begin now. We should initiate this work in order to put ourselves in the position to develop a comprehensive program plan in the near future.

In summary, continued leadership in aeronautics and space is crucial to the economic well-being and security of our Nation. Technological leadership is not an American birthright. We must continually earn it. Our fiscal year 1991 budget request is targeted at maintaining such leadership in the years ahead. We are here to ask your support for our efforts, and we would be pleased to answer questions you may have on any aspect of our program.

Thank you, Mr. Chairman.

[The statement and questions and answers follow:]

Statement of

Arnold D. Aldrich
Associate Administrator for
Aeronautics, Exploration and Technology

before the

Subcommittee on Science, Technology and Space
Committee on Commerce, Science and Transportation
U.S. Senate

Mr. Chairman and Members of the Subcommittee:

This is my first appearance before the Subcommittee as Associate Administrator for NASA's new Office of Aeronautics, Exploration and Technology (OAET). Earlier this year, NASA's Administrator, Admiral Richard H. Truly, asked that I provide a plan for merging the Office of Aeronautics and Space Technology (OAST) and the Office of Exploration (OEXP). The Administrator subsequently approved the recommended merger plan resulting in the establishment of OAET, which enables two closely related tasks, the definition of and planning for the Space Exploration Initiative (SEI) and identification and development of the new technologies required for SEI, to be fully integrated and to benefit from a focused management structure. The new organization continues to emphasize NASA's critically important aeronautics research and technology program and our commitment to advance technologies for current and future space missions, while pursuing exploration planning in a cohesive, strategic fashion.

As Associate Administrator, I am responsible for four major program areas and three of the NASA field centers. The centers are the Langley Research Center in Hampton, Virginia; the Lewis Research Center in Cleveland, Ohio; and the Ames Research Center at Moffett Field, California, which includes the Dryden Flight Research Facility at Edwards Air Force Base, California. While today's testimony will concentrate on program areas, I want to emphasize the importance of these four installations with a civil service staff of 7,999 full-time equivalents and a current research facility replacement value of $5.9 billion. As world-class research institutions, these centers constitute unique and extraordinary national resources. They consist of facilities and people whose work helps assure the United States remains preeminent in aeronautics and astronautics. OAET also supports critical Space Research and Technology programs at the other NASA field centers, including Johnson Space Center in Houston, Texas; Goddard Space Flight Center in Greenbelt, Maryland; Marshall Space Flight Center in Huntsville, Alabama; Kennedy Space Center in Florida; and the Jet Propulsion Laboratory in Pasadena, California. The Space Exploration Initiative and NASA's Space Research and Technology program will involve broad and active participation by all of the NASA field centers.

I am pleased to present NASA's FY 1991 Aeronautics, Transatmospheric, Space Research and Technology (R&T) and Exploration Mission Studies budget requests. With the critical investments proposed in this budget request, we can look forward to an exciting future in both aeronautics and space. For FY 1991, NASA is requesting $512.0 million for Aeronautics R&T; $119.0 million for Transatmospheric R&T; $495.9 million for Space R&T, which includes $179.4 million for the Exploration Technology Program; and $37.0 million for Exploration Mission Studies.

AERONAUTICS

The Aeronautics Research and Technology budget request supports a program constructed to strengthen the United States' leadership in aeronautics. It provides for a foundation of advanced technology upon which our industry can build to maintain our competitive posture in global aviation markets in the future. Of the total Aeronautics request of $512.0 million, $353.4 million is for the R&T Base and $158.6 million is for Systems Technology.

This month marks the 75th anniversary of the founding of NASA's predecessor, the National Advisory Committee for Aeronautics (NACA), and the birth of this nation's commitment to preeminence in aviation. Since the establishment of NACA in 1915, through the formation of NASA in 1958, and into the 1990's, our aeronautics program has represented an important technological resource within the United States, broadly contributing to both civil and military aviation. These 75 years have forged a strong partnership with industry and academia which has been the foundation for major aviation advancements and which still serves today as the model for cooperation in other fields. Today, the United States is the world leader in aviation. Our aeronautical products continue to provide the largest positive contribution to our country's trade balance and our aircraft are superior in performance and reliability. But our leadership is being challenged today as never before.

Strong foreign competitors are capturing an increasing share of important worldwide aviation markets. These competitors recognize the importance of advanced technology as a competitive factor and are committed to continuing the aggressive investments required to maintain their momentum in aeronautical research and development.

In addition, there is a continuing need to maintain the productivity and safety of our national air transportation system. Passenger revenue miles have tripled since 1970 and are expected to double again by the year 2000, further straining airport capacity and increasing the frequency of costly and annoying delays. And, aircraft themselves are a growing concern, as U.S. airlines enter the 1990's on the wings of the oldest civilian fleet in history.

NASA, with its industry and university partners, has worked to provide the technology instrumental in maintaining aeronautical preeminence. Through this close relationship with industry and the users of its products, we understand the technological advances required to keep the United States in front, and we have taken steps to reorient our program to keep abreast of changing times. However, there is more that can be done to assure continued United States leadership in aeronautics.

Both the emerging challenge of foreign competition to the Nation's aeronautics industry and the tremendous opportunities open for technological advances and leadership were identified by the Office of Science and Technology Policy (OSTP) report entitled National Aeronautical R&D Goals: Technology for America's Future. A second OSTP report, National Aeronautical R&D Goals: Agenda for Achievement, updated the competitive situation and provided a detailed eight-point action plan for coordinating the efforts of industry, academia, and the government to ensure that U.S. industry remains a viable competitor in the world aviation marketplace. Together these reports outlined national goals in the transatmospheric, supersonic and subsonic flight regimes to focus high-leverage technology developments, and concluded with a broad strategy for revitalizing the Nation's capacities for innovation in aeronautical research and technology.

NASA's strategy for aeronautics research and technology represents a vigorous, but appropriate, response to the overall aviation environment within the context of the above-mentioned national goals and action plan. Our programs continue to emphasize high-payoff emerging technologies, to ensure the health and productivity of unique laboratories and facilities and to address critical barriers to the introduction of new technologies and aircraft concepts. To implement this strategy we are pursuing six key thrusts:

- Subsonic Transports - develop high-leverage technologies to ensure future competitiveness of U.S. subsonic aircraft and to enhance the safety and productivity of the National Airspace System

- High-Speed Civil Transports - resolve the critical environmental issues and establish the technology foundation for future decisions on economical, high-speed air transportation

- High-Performance Aircraft - provide technology options for revolutionary new capabilities in future high-performance fixed and rotary wing aircraft

- Hypersonics/Transatmospherics - develop critical technologies to support the development of future hypersonic and transatmospheric vehicles

- Fundamental Technology Base - pioneer the development of the fundamental knowledge base for the design and operation of advanced aerospace systems

- Critical National Facilities - develop, maintain and operate critical national facilities for aeronautical research and for support of industry, DOD, and other NASA programs

NASA has formulated an agenda in line with these six strategic thrusts to methodically address overall national needs in aeronautics. The FY 1991 budget request supports this agenda with particular emphasis on addressing environmental issues associated with high-speed transportation, developing advanced composite materials technology for future airframes and engines, strengthening NASA/FAA cooperation in addressing congestion and air safety, and maintaining our commitment to a strong national facility capability.

In line with our first thrust in Subsonic Transports, our FY 1991 program reflects research leading to advances in aircraft flight systems, aerodynamics, and propulsion that can combine to offer efficient subsonic transports operating in a safe and productive National Airspace System.

To further enhance the safety and capacity of the National Airspace System, we have strengthened our cooperation with the FAA and renewed our research and technology effort dedicated to developing long-term technology solutions to support the FAA in addressing aviation safety, aging aircraft and congestion. An agreement between the FAA and NASA was signed by the respective Administrators in January 1990 which formally reconstituted the FAA-NASA Coordinating Committee and outlined a top-level framework for cooperation composed of six major areas of focus: Human Factors, Severe Weather, Environmental Compatibility, Cockpit/Air Traffic Control (ATC) Integration, Airworthiness and Program Support. Ongoing and new cooperative research and development activities will be jointly pursued in these program areas.

Cooperative NASA-FAA efforts continue to produce excellent results that are contributing directly to safety and efficiency in the National Airspace System. A unique Engine Monitoring and Control System (E-MACS) display has been developed which allows pilots to quickly assess the performance and status of the aircraft's engines during high pilot workload situations such as takeoff and landing. Significant improvements over conventional display systems in detecting engine faults or abnormalities have been demonstrated. Research on the detection and avoidance of severe windshear hazards during terminal area operations has resulted in a new windshear hazard index. This index, which directly indicates the effect of windshear on aircraft performance, has received wide industry interest. Continuing cooperative research in this area focuses on in-flight windshear detection sensors and flight management concepts to reduce the risk associated with windshear encounters. Cooperative research focused on FAA and airline operators' concerns about aging aircraft are being addressed through the development of Non-Destructive Evaluation (NDE) techniques capable of scanning large sections of aircraft structures for fatigue and corrosion damage. A thermal imaging NDE system is currently being developed for demonstration.

Advanced turboprops offer potential for significant gains for subsonic transport aircraft; however, a concern remains about noise observed on the ground from aircraft flying at cruise condition. NASA, in cooperation with the FAA, employed the Propfan Test Assessment (PTA) aircraft to obtain a unique data base for enroute noise. These ground noise measurements provide the basis for understanding source noise propagation to ground level and its variations due to atmospheric conditions. The data are now being analyzed to help develop and verify the advanced, analytical prediction codes for future design application. This concludes the large-scale flight testing element of the Advanced Turboprop Program and establishes a data base for design of future turboprop powered aircraft.

Advances in materials and structures technology provide major opportunities for improvements in performance of subsonic aircraft through reduced airframe structural weight and higher temperature propulsion systems. Our Advanced Composite Materials Technology Program activities include development of organic polymers for high-temperature, toughened thermoset and easily processible thermoplastic composites for future airframe structures. These materials are being incorporated in advanced structural concepts to identify opportunities for reducing composites fabrication cost using advanced processes. A new composite fabrication concept, known as Resin Transfer Molding (RTM), has been developed which can reduce production costs up to 25 percent and weight by 40 percent relative to current aluminum airframe structures. This process uses low-cost composite materials and can be automated to further reduce manufacturing cost. The RTM concept was demonstrated in FY 1990 by fabricating a large stiffened panel representative of a wing element with the strength and damage tolerance required for commercial applications. In FY 1991 program efforts will be increased to design, fabricate and test larger scale subcomponents to verify innovative, low-cost composite structures technology which is applicable to aircraft wings and fuselages. The initial verification of composite design and analysis methods for these large-scale structural components will provide a baseline for future development of full-scale composite structures.

Our Advanced High Temperature Engine Materials Technology Program focuses on providing revolutionary composite materials and structural analysis techniques for 21st century subsonic transport engines. Composites have been fabricated which maintain strength and toughness after thermal cycling from room temperature to 1100 degrees Centigrade for over 500 cycles, an environment which is characteristic of that experienced by jet engine compressors and turbines.

Our thrust in High-Speed Civil Transports is addressed primarily through the High-Speed Research (HSR) Program we initiated in FY 1990. As planned, we are significantly increasing our efforts in this program which was directed at critical environmental compatibility issues and establishment of a foundation for subsequent decisions on future high-speed civil transport technology and development programs.

International air travel is an integral part of today's global marketplace. While subsonic transports will continue to be an important market segment, high-speed aircraft will likely be the next plateau of competition in the international aviation arena. Currently, however, three critical environmental concerns: atmospheric impact, airport noise, and sonic boom, present powerful private sector disincentives. The HSR Program focuses on each of these concerns. It builds on NASA's extensive efforts in upper atmospheric research and previous experience in airport noise and sonic boom reduction technology to resolve these three barrier environmental issues and to develop the basis for evaluating technology advances that can provide the necessary environmental compatibility. Resolution of these critical environmental issues will place the U.S. in a position to make informed decisions on high-speed aircraft technology development in the future.

The first HSR element, atmospheric impact, involves two research efforts: long-term atmospheric chemistry assessment and low emission combustion research. A committee of eminent scientists from NASA's Upper Atmosphere Research Program is guiding the study of the possible long term effects of high-speed civil transport aircraft operation on atmospheric chemistry and climatology, with special emphasis on ozone. Twenty grants and contracts are being sponsored in the current fiscal year to develop improved computer-based models of the lower stratosphere and tropopause, examine nitrogen oxide (NOx)/ozone chemistry in the laboratory, and begin planning for in-flight experiments. In FY 1991, we will expand the scientific community involvement and intensify the global atmospheric assessment activity. In parallel with this effort, we are conducting low emission combustion research involving the development and test of alternative methods for reducing or eliminating engine exhaust products that cause ozone depletion. The primary focus is to develop advanced technology combustor designs which produce very low amounts of NOx emissions. In FY 1991, we will be emphasizing testing of experimental hardware in addition to analytical studies.

The second HSR element, noise reduction, involves research on alternative engine cycles and jet noise suppression aimed at providing the acoustic levels equal to those of today's quietest subsonic aircraft. Source noise research in FY 1991 will shift to increased screening of concepts that have the potential to meet reduction goals. Early results from wind tunnel experiments of advanced jet noise suppressors have shown promise, but considerable work will be required to achieve the desired noise levels.

The third HSR element, sonic boom reduction, includes aircraft configuration research aimed at reducing sonic boom levels and conducting human response evaluations to define criteria for acceptability. Airframe technologies that promise synergistic benefits for sonic boom, noise and emissions by reducing weight or improving aerodynamics are being studied. This work will transition to increased wind tunnel and flight research in FY 1991. High-lift and sonic boom wind tunnel models will be designed and fabricated for subsequent concept assessment and analysis validation. Supersonic laminar flow control experimental research will expand with completion of the F-16XL flight test evaluation of a passive glove and initial design of a wing leading edge with suction.

Our thrust in High-Performance Aircraft is focusing on providing a proven technology base to enable unprecedented levels of maneuverability and agility of fighter aircraft and to ready the technology base for supersonic STOVL aircraft and advanced rotorcraft.

NASA continues to cooperate with DOD to provide technology options to enable superior military aircraft. The High Angle-of-Attack Technology Program is a comprehensive aerodynamics, flight dynamics and control research program that is exploring the lower-speed, high angle-of-attack portions of the flight envelope that may provide tactical advantages through increased agility and maneuverability.

The program, which contains analytical, computational, wind tunnel, and flight research elements, was augmented in FY 1990 to expand validation to extremely high angles-of-attack. A detailed data base has been developed for the F/A-18 aircraft with conventional and advanced research control systems. A thrust vectoring control system for both pitch and yaw control will be installed and both computers and wind tunnels will be utilized to design forebody yaw control systems. Data, important for computational methods validation, have been obtained that enable comparisons of predicted and flight measured aerodynamic flow characteristics. In FY 1991 we will conduct flight evaluations of the enhanced maneuverability resulting from the thrust vectoring control system.

Full-scale tests of the E-7A supersonic Short Takeoff and Vertical Landing (STOVL) fighter successfully validated ejector/augmentor performance required for hover and low-speed flight. This cooperative STOVL research and technology program is jointly funded by NASA, DARPA, and the Department of Industry, Science and Technology of Canada. The full-scale powered model of an E-7A aircraft was tested in both the 40- by 80-foot and 80- by 120-foot test sections of the National Full-Scale Aerodynamics Complex (NFAC) at Ames Research Center. Aerodynamic performance of the de Havilland designed ejector on the full-scale aircraft was very good, achieving an augmentation ratio of 1.58, the highest full-scale aircraft augmentation to date. The U.S./U.K. ASTOVL program is continuing to jointly develop a common technology set including controls, nozzles, hot gas ingestion, ducts and valves, and ground erosion.

The Rotorcraft research and technology program is primarily focused on high-speed configurations. Simulation experiments of tiltrotor configurations have shown advantages for enhanced maneuverability. Large-scale wind tunnel investigations have validated tiltrotor performance predictions. Small scale tests are also investigating the feasibility of advanced configurations. These studies are continuing to identify the technology needs of high-speed rotorcraft and will provide a framework for future rotorcraft research.

Our Hypersonics/Transatmospherics thrust is to develop critical technologies to support the development of future hypersonic and transatmospheric vehicles. NASA's primary focus is the National Aero-Space Plane (NASP) program, a major national effort to develop, and then demonstrate in flight, the most critical technologies to enable single-stage-to-orbit with airbreathing primary propulsion. This is complemented by a hypersonic research effort within the Aeronautics research and technology base program which stresses fundamental understanding of the controlling physical and chemical phenomena for hypersonic vehicles and engines. Specific issue areas include boundary layer transition at high Mach numbers, turbulent mixing and mixing enhancement, and very high-payoff metal-matrix composite materials. Advancing methodology for integrating technology disciplines is a significant emphasis.

Our Fundamental Technology Base thrust emphasizes fundamental research, cross-cutting technology development, and validation of numerical simulation techniques to maintain the theoretical, experimental and predictive foundation necessary to extend our aviation preeminence into the future. New and innovative approaches combining advanced computer architectures, algorithms and software are being pursued to enhance our capabilities to simulate the complex behavior of aerodynamics, materials, structural mechanics and chemically reacting flows. We are working to mature critical numerical simulation for application to the design and analysis of aerospace vehicle components and to pioneer the technology base to enable the multidisciplinary design and simulation of complete vehicle and propulsion systems.

We continue to enhance the pathfinding capability of the Numerical Aerodynamic Simulation (NAS) system at Ames Research Center. We have upgraded the main memory capacity of High-Speed Processor-2 from 32 to 128 million words (this was the first installation of the new 128 million word version of the Cray Y-MP supercomputer) and we plan to replace our first high-speed processor with the next generation of supercomputers in FY 1991. The NAS continues to be used to pioneer new simulation capabilities over a broad range of aerospace applications including structural mechanics, aeroelasticity, turbo-machinery, rotorcraft and powered lift modeling, as well as Space Transportation System and National Aero-Space Plane support. During last year more than 1150 researchers, working on 460 projects, accessed NAS from 120 remote sites. Researchers accessing the NAS from our Langley Research Center developed a new highly efficient structural analysis code for application to the Space Shuttle solid rocket motor case. The method fully exploited the parallel and vector processing capabilities of the 8-processor Cray Y-MP to achieve a computational speed of 1.34 billion operations per second, one of the highest speeds ever accomplished, on a very large, 55,000 degree-of-freedom finite element analysis. Researchers developed the capability to simulate flows about realistic aerodynamic bodies in relative motion. This new capability has been used to simulate the separation of the Solid Rocket Boosters (SRB) from the Space Shuttle. The computational tool is applicable to a wide range of space flight applications, such as Space Shuttle. SRB and External Tank separation sequences, staging sequences of multistage launch vehicles, and the release sequence of the Pegasus satellite launch vehicle; and aeronautics applications, such as stores separation from high-performance aircraft and ground/aircraft interaction during takeoff and landing of STOVL aircraft.

As part of our work in computer science, we have increased our emphasis on research into innovative approaches to achieving significantly higher performance computing capabilities for single and multiple discipline simulations. We have developed and demonstrated new computational fluid dynamics algorithms and other aeronautics applications on massively parallel computers and have expanded our investigation of alternate architectures to include parallel computers implemented with the newest and most powerful Reduced Instruction Set Computer (RISC) based microprocessors. We are continuing to work actively with the other members of the government high-performance computing team to define NASA's role in the multi-agency High Performance Computing program.

Investments in propulsion technology continue to be a major pacing item in achieving improvements in aircraft system performance and the understanding of the complex flow inside an engine is the key to achieving further advances in propulsion technology. Researchers at Lewis Research Center recently completed successful development of a multistage turbomachinery computer code which, for the first time, provides the capability to analyze complex three-dimensional flow fields, including secondary vortices caused by viscous effects. Using a modern supercomputer, this code, when applied to two full compressor stages, predicted the same flow choking phenomena seen in experiments and heretofore uncaptured by analytical methods. We are currently utilizing ongoing low-speed and high-speed turbomachinery experiments to further develop the computer model for improved accuracy and reduced computer time.

Our research program is placing strong emphasis on fundamental fluid physics and materials research, both of which will lead to the development of new and enabling technologies that will be key to aviation advances in the next century. Understanding of the basic physical nature of fluid flows remains key to the design of efficient aircraft and propulsion systems of all kinds. We are increasing our focus on obtaining a physical understanding of boundary layer transition and turbulence which is the major barrier to achieving a complete understanding of fluid physics. With this understanding we can develop and verify new powerful techniques for active control of boundary layer transition and turbulence over airframes, and within engine inlets and nozzles. The objective of our advanced materials program is to develop and validate the technology base to enable the broad use of advanced materials in future airframe and propulsion structures. Generation of a research data base will promote improvements in performance, safety, and durability of aircraft, as well as reduce weight and life cycle cost. The materials program continues to place a strong emphasis on developing basic understanding and technology relationships among processing parameters and material properties, including both monolithic and composite materials, with particular focus on high-temperature applications.

Finally, the Critical National Facilities thrust is addressed though an augmentation for maintenance of facilities, in addition to the five-year NASA Major Wind Tunnel Revitalization program which began in FY 1989.

NASA remains committed to, and supports, a strong national capability through unique facilities and technical expertise. We are the steward of the Nation's major Aeronautical test facilities. We have included in this request the third increment of the 5-year Major Wind Tunnel Revitalization Program. The Hypersonics complex at Langley Research Center and the 10x10 at Lewis Research Center are in the construction phase and are on schedule. The Ames Research Center 12-Foot Wind Tunnel design is complete and the site is ready for construction. The final designs of the FY 1990 projects are progressing well and expected to be ready for the start of construction this fiscal year. The FY 1991 plan will address the upgrade of five major tunnels located at Lewis and Langley Research Centers.

Our FY 1991 request includes a facilities maintenance augmentation. Over one-half of NASA's national facilities are thirty years of age and many are approaching fifty years of age. Historically, maintenance of our facilities has been underfunded to the point that their operational capability and productivity have been adversely affected. This augmentation is critical to correct this problem. It includes increased maintenance of cooling systems, auxiliary equipment and roofs; corrosion control of major wind tunnels; and increased preventive maintenance on elements of facility power systems, heating, air conditioning, and other utility systems.

TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY

The NASA budget request in FY 1991 for the National Aero-Space Plane (NASP) program, a joint program with the Department of Defense (DoD), is $119 million in Transatmospheric Research and Technology. NASP is a technically demanding technology program, essential to the future of the United States. NASP is important because it advances technology in key fields such as propulsion, materials, structures and computational sciences whose application, though critical to future aerospace vehicles, extends beyond aerospace into other U.S. industries. NASP is important because, as launch vehicles and Airbus demonstrate, aerospace is an internationally competitive endeavor where U.S. preeminence is under direct challenge. That both Europe and Japan (and perhaps the U.S.S.R.) are pursuing hypersonic vehicles should not go unnoticed. Finally, NASP is important because it points to the future, stating clearly that the hypersonic vehicles we fly in both the civil and military sectors in the 21st Century will be designed and built in the U.S.

The NASA budget request for the NASP is consistent with the recommendation made by the National Space Council in its July 1989 report on NASP. The request represents the required level of funding to support the crucial propulsion system and airframe analyses and testing leading to the X-30 decision. In addition to its direct funding support to the program, NASA also provides substantial and vital institutional support made up of technical specialists, wind tunnel and propulsion test facilities and supercomputers.

The National Space Council review last summer led to many significant improvements in the program and, as a consequence, it has benefited by being stronger now than ever. Both NASA and Air Force management have reaffirmed their whole-hearted commitment to the program. The Steering Group, which is chaired by the Under Secretary of Defense for Acquisition, now has the NASA Deputy Administrator as the Vice Chairman, with the Associate Administrator for OAET remaining as a key member. An indepth Quarterly Technical Review process has been initiated which involves the NASA Deputy Administrator, Associate Administrator for OAET, the three NASA Research Center Directors, the Air Force Under Secretary for Acquisition and DoD Laboratory Directors. We believe this process will be extremely valuable in keeping the program on track and in keeping senior management close to the technical and programmatic status.

On the contractor side, there has been a major commitment to a unique teaming arrangement whereby all five competing contractors can now participate together, with full cooperation, toward the common objective of a viable X-30. The benefits of teaming include eliminating duplication of effort and the accelerating pace and synergisms resulting from technology sharing within a single team. Also, Government researchers will be able to contribute directly rather than through "generic" data as required by competition. The contractors are able to remain open to the benefits of technology spinoffs and still be genuine competitors on future

NASP-derived concepts. NASP is probably the ideal program for such a bold contractual approach because of the challenge of the vehicle and the fact that each contractor has excellent ideas, concepts and expertise. All contractors have recognized these many benefits and enthusiastically support this teaming plan. The commitment of a new Steering Group and senior agency management, and the new contractor team, give the NASP program a much stronger and more cohesive posture for the remainder of the current technology phase --Phase II-- and beyond.

At its Fall meeting, the Steering Group strongly recommitted to the single-stage-to-orbit goal for the program. An incremental approach to the X-30 is being pursued in which a robust design philosophy allows upgrades in components and subsystems to be incorporated into any future vehicle as advances in technology continue. The contractor teaming allows all of these efforts to be highly focused toward the eventual optimized configuration.

Technical progress is being made on all fronts. The technical status continues to be quite impressive and appropriate to the current schedule. For example, both Pratt and Whitney and Rocketdyne have conducted "large-scale" tests of engine combustor hardware up to Mach 8 conditions, and both have tested subscale propulsion module tests in the speed range of Mach 4 to 8. Levels of performance have been achieved which give confidence that the necessary values can be achieved at these conditions. Evaluation of the "large-scale" total propulsion system package, including transitions of engine operating mode, remains a challenge, as does generation of sufficient data in the very high Mach number regime.

Work in materials and structures has demonstrated significant progress toward high-temperature performance at very light weights. Representative, large-scale structures have been built from advanced materials such as titanium-aluminides and carbon-carbon composites. The greatest challenges remain in demonstrating scale-up of these structures to appropriate aircraft panels and in actively-cooled structures which are required in high heat flow areas such as engines. Compatibility of new materials with hydrogen is also a remaining issue.

Aerodynamic technology is also advancing. There is a substantial data base on a variety of configurations, and current computational fluid dynamics tools are achieving good correlation with existing data. Methods are still being evolved for predicting mixing (and hence combustion efficiency) in engine flows and for determining transition from laminar to turbulent flow. The latter is important for predicting local aerodynamic heating and engine-inlet flow.

NASA has been a prime contributor to the progress to date. More than 300 civil service employees at the Langley, Lewis, and Ames Research Centers are committed to NASP. Many of these are the same technical specialists who maintained the national expertise in hypersonics in the years prior to NASP and are, therefore, heavily relied upon for oversight and consulting as well as the conduct of technical tasks. Wind tunnel tests of many competing aircraft configurations covering the speed range from takeoff to Mach 20 have been conducted in NASA facilities. Conventional force, moment and pressure measurements have been made, but also special issues such as ground-effect on landing and takeoff (in Langley's 14' x 22' Tunnel) have been investigated. The subscale engine module tests, which have been so important to the propulsion contractors, are still being conducted in Langley's two supersonic combustion ramjet (scramjet) test facilities, and the Lewis Research Center has taken the lead for the program in the area of slush hydrogen. The Numerical Aerodynamic Simulator at Ames, the Nation's premier supercomputing facility, has continued to be heavily committed, at about 30 percent of its capacity, to NASP. Class VI computers at other centers are also being used. In fact, the NASP program has pushed the application of advanced computational techniques to levels far exceeding any other program, and the full capability of our computers has been taxed at times.

SPACE RESEARCH AND TECHNOLOGY

Technology is an essential element of "investing in the future"-- a message that the President has sent along with this budget request to Congress. The FY 1991 request of $495.9 million represents a continued commitment to providing technology that enables and enhances future space missions.

Our technology program contributes significantly to space missions by increasing mission safety and reliability, reducing development and operations costs and enhancing mission performance and benefit. Further, it strengthens the Nation's aerospace capabilities by building strong partnerships with industry and the university community as well as revitalizing and expanding NASA's capabilities. Technology programs provide both stimulus and support to the education of the next generation of engineers and scientists.

Advancements in technology made possible the past achievements of the civil space program. The technologies developed for Apollo in areas such as propulsion and guidance, navigation, and control allowed our Nation to initiate our quest to explore other planetary bodies. NASA continued this tradition with the Space Shuttle Program where critical developments in thermal protection, propulsion and avionics enabled the development and operation of the manned reusable space vehicle which regularly performs a wide variety of important missions.

Technology developments in power, automation, robotics, and structures will enable us to build Space Station Freedom, a permanently manned facility in space, during the 1990's. Technology developments in sensors and power systems helped us learn more about our planet Earth and the solar system through such spacecraft as Seasat, Viking, and Voyager. Our technology efforts will continue to support the next generation of science missions and will be the foundation for success in the exploration and expansion of human presence throughout the solar system.

The Space Research and Technology strategy is to provide a balanced, multidisciplinary program necessary to meet the Nation's spacefaring needs and goals. It responds to the President's initiatives in space transportation, Space Station Freedom, space science research and solar system exploration including support to the Earth Observing System. The OAET technology program covers:

- Transportation - by providing technology for reliable transportation systems with high performance, predictable service life and dependable operations costs. These efforts will:
    - develop design improvements for Space Shuttle Main Engine (SSME) high pressure turbopump blades and bearings as well as development of sensing techniques to more accurately detect impending engine failures and permit early, safe shutdown.
    - increase safety, reliability, reusability and serviceability of the current Space Shuttle System and provide for expansion of its capabilities.
    - develop technology for engine turbopump and hydrostatic bearings which can significantly improve the efficiency and life of the Advanced Launch Systems (ALS) Engine, the space-based chemical transfer engine and future upgrades of the SSME.
    - enable advanced manned and unmanned launch systems and space transfer vehicles.
- Space Station - by providing technology for the current and evolutionary phases of the Space Station Freedom Program. These efforts will:
    - expand capability and reduce the life cycle cost of Space Station operations. OAET-supported technology products which will be incorporated into the initial Space Station Freedom include large flexible solar arrays, large area silicon cells and nickel-hydrogen batteries in the power system; and on-orbit erectable truss structures.
    - develop improvements in automation and expert systems which will free up valuable crew time by assisting in maintenance of the Space Station and in robotics to allow us to conduct more experiments outside the manned facility.
    - enhance capabilities as a testbed to conduct technology development and validation.
    - develop cryogenic fluid transfer experiments which will improve our understanding of how to handle propulsion fluids in space in order to support lunar and Mars transfer vehicle fueling and refueling.
    - enhance capability as a transportation node for the future Exploration program.
- Space Science - by providing technology for Space Science programs focused on the planet Earth, the solar system, and the universe. These efforts will:

  - develop technology advances in a variety of areas including power systems and sensors which will enhance the benefit from science missions, such as the Earth Observing System, the Advanced X-ray Astrophysics Facility (AXAF), the Comet Rendezvous and Asteroid Flyby (CRAF)/Cassini missions, and the Space Infrared Telescope Facility (SIRTF).

  - enhance science mission performance and information return and reduce costs through technology advancements.

- Exploration - by striving to define and pursue key technologies for future Exploration Missions, including those required for the establishment of an outpost on the Moon and exploration of the planet Mars. These efforts will:

  - develop new and innovative capabilities, including aerobraking, in-space vehicle refueling, planetary rovers, and advanced electrical power, propulsion, and closed-loop life support systems

  - enable us to explore the solar system using both robotic and human missions.

- Breakthrough - by pursuing advanced technological concepts which have the potential for major evolutionary or revolutionary applications. These efforts will:

  - stimulate and explore advanced high-risk, high payoff technologies that have the potential to revolutionize the approach to future programs. Examples include:

    - Superconductivity. Due to the huge potential payoff in weight, size, and operational flexibility, the first application of the dramatic advances in superconducting materials may be in electronics and power and propulsion systems for space applications. Studies and experimental efforts are underway to define these applications and to evaluate superconducting materials under space conditions.

    - the assessment of a concept for a revolutionary fuel cell power system which could use the atmosphere of the Mars environment as one of the reactants.

This budget request provides the resources necessary to implement a balanced technology program, one truly critical to realizing the agency's goals. The Space Research and Technology Program consists of four elements. The first, the Research and Technology Base program, supports core research in technical disciplines. The second, the Civil Space Technology Initiative, addresses research and technology to enhance near-term space missions. The third element is the In-Space Technology Experiments program. This supports the development and validation of technology in space. The fourth element, the Exploration Technology Program (formerly Pathfinder) will lay the building blocks needed to expand human presence and activity into the solar system. Let me now highlight some of our accomplishments over the past year in these areas and point out what we intend to accomplish with the FY 1991 funds.

Research and Technology Base

The FY 1991 request for the R&T Base is $125.7 million. This will support core disciplinary research in aerothermodynamics, materials and structures, power and propulsion, life sciences, human factors, information systems, and other key space technology fields. Included in this request are funds for the University Space Engineering Research Center program which was initiated in 1988.

There were several major accomplishments in FY 1990--including the vast amount of unique data which we are obtaining from the Long Duration Exposure Facility (LDEF). The LDEF spacecraft was retrieved in January 1990 after five and a half years in space. The 57 experiments onboard and the spacecraft itself will provide invaluable information on the long-term effect of exposure to the space environment. We will be studying space debris and meteoroid impact effects as well as environmental and atomic oxygen effects on materials and coatings, thermal systems, electronics, and optics. The knowledge attained from LDEF will allow us to make significant strides in research in support of Space Station, Space Science and Exploration space system designs.

In FY 1991, we plan to emphasize critical research in fundamental disciplines that will provide technology for future Earth observing and exploration missions. This will include research in sensor cooler technology and infrared detectors. In addition, studies of fundamental chemical processes important to the understanding of physical-chemical systems for closed-loop life support will continue.

Civil Space Technology Initiative (CSTI)

The CSTI program was initiated in 1988 to advance technology beyond basic research in order to expand and enhance system and vehicle capabilities for near-term missions. CSTI takes critical technologies to the point that the user can confidently incorporate these new or expanded capabilities into relatively near-term NASA missions. In particular, CSTI focuses on providing technology for reliable and cost-effective access to, operations in, and science missions from Earth orbit.

The CSTI program has already produced significant accomplishments. For example, in support of the agency's requirements in transportation, the Earth-to-orbit research effort has developed increased turbopump bearing durability and resistance to stress corrosion cracking. This will contribute directly to the safety and serviceability of the Space Shuttle Main Engine (SSME). We have also installed a prototype optical plume anomaly detector system for evaluation in the technology testbed stand at the Marshall Space Flight Center. This system will allow detection of incipient failures in propulsion systems prior to engine failure thus enhancing information return and reducing hardware loss. In support of

Space Science, an expert system, developed as part of our artificial intelligence research efforts, was used during the Voyager encounter with Neptune last August. This system successfully detected anomalies in the telemetry, diagnosed possible causes and provided valuable information in identifying possible solutions.

However, as you are aware, this program was reduced by $20.7 million from our requested level in FY 1990. As a result, one of the important technology elements in the program, the booster research effort, was essentially terminated. We intend to support a modest amount of the highest priority basic research in this area utilizing funds in the R&T Base. In addition, because of the budget reduction, technology delivery dates and planned technical accomplishments were slipped and stretched out in other areas, including automation, robotics, Earth-to-orbit propulsion and the control of flexible structures.

Our FY 1991 request of $171.0 million will allow us to continue to provide new and enhanced capabilities to users for incorporation of new technologies into their missions. We intend to maintain support for Space Station applications through focused research in automation and robotics and control of structures, for space science missions through research in precision structures, high-rate data systems, and sensor technology, and for transportation safety and reliability through research in Earth-to-orbit propulsion. For solar system exploration missions, CSTI activities in high capacity power and aerobraking are focused on critical enabling technologies. The Aeroassist Flight Experiment will contribute to significantly reducing the mass of propellant needed to be launched into orbit for planetary missions through the development of aerobraking techniques. The high capacity power program is developing technology options to enhance the performance and power output of space nuclear power systems. These are highly important for large lunar base activities and critical for major missions to the planets.

Exploration Technology Program

As previously mentioned, we are requesting $179.4 million in FY 1991 for the Exploration Technology Program to meet the challenge of President Bush's new vision of space exploration. The Exploration Technology Program will pursue development of a wide range of critical technologies needed for the return to the Moon and human and robotic voyages to Mars. This program will involve technologists and engineers from the full spectrum of the U.S. aerospace community including NASA Centers, national laboratories, industrial firms, and universities.

The Exploration Technology Program represents a start--not of a program plan--but of a technology investment needed for future program decisions. With these funds, we will expand technology investments which will enable a variety of strategies for mission architectures. We will focus on technologies that can increase safety and reliability, reduce risks and costs, and enhance mission performance.

During the last several years numerous national studies have assessed the need for significant investments in technology for future Exploration missions. In response to these findings and as part of the National Space Policy, the Pathfinder Program was initiated in FY 1989. We have recently reassessed the present results of

Pathfinder and a wide range of technology challenges for the Space Exploration Initiative. We need to go beyond this initial analysis and the funds we have requested will enable us to do so.

The Exploration Technology Program for FY 1991 consists of the previously planned Pathfinder Program as a foundation with augmentation to address a broader range of critical enabling technologies. Key challenges in the augmented program include aerobraking, space-based engines, regenerative life support, space nuclear power, in-situ resource utilization, space nuclear propulsion and many others.

Although FY 1990 funding for exploration technology (Pathfinder) was reduced from our request, we have maintained critical inter-Center and industry teams and maintained contracts and interagency commitments. We are ready to move out quickly in support of the President's vision of a "long-range, continuing commitment" to exploration. We have continued an effective pace in the development of space nuclear power through the SP-100 program, an interagency research effort which includes the Department of Energy, Department of Defense, and NASA. We have also had exciting developments in a number of other areas including the planetary rover project at Carnegie Mellon University where a six-legged rover is being developed that will be able to safely traverse obstacles two meters tall, crevices two meters wide and areas with 40 degree slopes. A six-legged testbed assembly has been completed and it took its first steps in December.

Emphasis in implementing the Exploration Technology program in FY 1991 will be on critical technologies for both robotic and human exploration in seven key areas: space transportation, in-space operations, surface operations, human support, lunar and Mars Science, information systems and automation, nuclear propulsion, innovative technologies and systems analysis. Over the next several years, we will be developing a wide range of technologies for SEI, many of which benefit life on Earth. To look at just one example, establishing a permanent presence on another planetary surface requires the development of new power technologies and regenerative life support systems. These may well lead to new environmental monitoring and waste management systems and safer, more efficient power systems for use on Earth which can be of great benefit as we strive to preserve our fragile planet. We know that the Apollo program and subsequent NASA programs have resulted in many "spinoff" technologies -- many more will be generated by this long-term, continuing commitment to space.

In-Space Technology Experiments

An important element of the Space Research and Technology program is the In-Space Technology Experiments activity. We are requesting $19.8 million in FY 1991 to support this effort. The objective of this program is the development of flight experiments to test highly innovative technologies which require research, testing and validation in the space environment. Taking these experiments into space will enable us to understand basic phenomena, reduce the risk to potential users, and increase the rate of technology transfer to future space missions. The wealth of data obtained from the retrieval of the Long Duration Exposure Facility

(LDEF) clearly demonstrates the benefits of acquiring data from the actual space environment in addition to ground-based research.

This program is designed to provide opportunities for the private sector and university space engineering communities to conduct in-space experiments. It is a new program initiated last year but it has already elicited strong support. In response to solicitations for experiment proposals which we have sent to industry, universities, and our internal NASA engineers and technologists, we have received over 300 excellent proposals. The areas of proposed research include fluid behavior in microgravity environments; the use of robotics in space construction, servicing, and other in-space operations; and environmental effects on materials from long-term exposure to the space environment.

In FY 1991, we intend to continue development of fourteen experiments that were initiated through this program and to support development of additional experiments from proposals received from industry, universities and NASA engineers.

A significant benefit of NASA programs is the synergism between our activities and those of U.S. aerospace industry and educational institutions. An objective of the Space R&T program is to strengthen U.S. engineering and technical talent throughout the university and industrial communities through the establishment of a strong partnership in technology research and development.

In the process of implementing our space research and technology program, we have established several activities specifically designed to encourage university engineering research. These include the University Space Engineering Research Center Program which supports nine inter-disciplinary engineering research centers engaged in innovative research and technology, the Investigators Research Program which provides grants to fund innovative research concepts, and the University Advanced Space Design Program which funds advanced systems study courses at the senior and graduate level.

EXPLORATION

The President's FY 1991 budget request for NASA demonstrates his commitment to a bold and exciting future in space. We are requesting $179.4 million in FY 1991 for the Exploration Technology Program and $37 million for Exploration Mission Studies to meet the challenge of President Bush's new vision of space exploration. Speaking on the twentieth anniversary of the Apollo 11 Moon landing, President Bush gave America a goal in space, and a pathway to get there. He said:

> "In 1961, it took a crisis --the space race--to speed things up. Today we do not have a crisis. We have an opportunity. To seize this opportunity, I am not proposing a 10-year plan like Apollo. I am proposing a long-range, continuing commitment. First, for the coming decade--for the 1990's--Space Station Freedom-- our critical next step in all our space endeavors. And next--for the new century--back to the Moon. Back to the future. And this time, back to stay. And then--a

journey into tomorrow--a journey to another planet--a manned mission to Mars."

The National Space Policy, developed by the National Space Council and signed by President Bush on November 2, 1989, updates and reaffirms U.S. goals and activities in space and provides a broad policy framework to guide future U.S. space activities. One of the goals stated in this policy is "to expand human presence and activity beyond Earth orbit into the solar system." The Space Exploration Initiative will fulfill this goal.

Moreover, the commitment to return to the Moon and journey to Mars is evidence that the American people retain the vision, courage, and skills essential to national well-being in the twenty-first century.

The reasons for undertaking the Space Exploration Initiative are compelling:

- To fulfill the human imperative to explore
- To enhance our understanding of life in the universe
- To gain knowledge about our planet's origin, evolution and global dynamics
- To improve this nation's technological competitiveness
- To continue America's journey into space.

As with our past space endeavors, we will reap great rewards by challenging ourselves to realize our dreams. We will increase our storehouse of knowledge about the planets, including our own, and about the nature of life itself. We will develop new technologies, many of which will have applications that will improve our lives on Earth. We will stimulate science and engineering education in this country by inspiring and motivating our young people. By pursuing our exploration goals, we will improve our competitive technological position in the world and bolster our national pride and international prestige. Each time we have gone to the frontier and beyond, we have brought back more than we hoped for. As we journey outward once again, we will bring back more than we can imagine.

This "long-term, continuing commitment" to excellence and achievement in space announced by President Bush requires a sustained, significant commitment of national resources. Instead of going and coming back as we did with Apollo, we are going to stay. This means developing the infrastructure to support a long-term future effort and carefully planning future missions while executing those nearer at hand. A steady budgetary commitment will enable NASA to fulfill its national missions: to continue making advances in aeronautics, proceed with our excellent space science work, keep the Space Shuttle flying safely, get Space Station Freedom up and operating, and meet the challenges of human exploration of the solar system.

NASA has been studying human space exploration since the early 1960's. Recently, a number of studies have provided a clearer vision of the U.S. future in space. In 1986, the National Commission on Space recommended a direction to advance the broader goals of twenty-first century America, "to lead the exploration and development of the space frontier, advancing science, technology, and enterprise and building institutions and systems that make accessible vast new resources and support human settlements beyond Earth orbit, from the highlands of the Moon to the plains of Mars." In her 1987 report to the NASA Administrator, "Leadership and America's Future in Space," Dr. Sally K. Ride laid out a strategy for U.S. leadership in space which culminates in the exploration of Mars by humans. In 1988, "Beyond Earth's Boundaries," the Office of Exploration's first report to the Administrator, provided the results of several case studies of possible pathways and strategies for human exploration of the solar system and identified the basic needs of these cases. These reports and studies laid the groundwork for the President's commitment to the Space Exploration Initiative.

The pathway defined by the President in his speech on July 20 will allow us to meet the goal of expanding human presence and activity in the solar system, with each step into space building on the previous one. The work we do on Space Station Freedom in the 1990's in life sciences, technology development and validation, and operations will provide experience and information essential for a permanent lunar outpost. Likewise, establishing a lunar outpost before sending humans to Mars is both prudent and of significant benefit. We will gain experience living and working on another planetary body which is relatively nearby while experiencing significantly less risk than an initial journey directly to Mars would entail while developing new technologies and operational procedures required for a planetary outpost. We will learn how to "live off the land," testing surface systems and using in-situ resources, in preparation for our journeys to Mars. We can do first-rate science on the Moon, particularly in geology and astronomy.

To proceed toward implementation of the President's goal, NASA carried out a 90-day study to provide preliminary information on the potential technologies, benefits and program architecture for space exploration. The five reference approaches examined in the report provided a database of current information and a foundation for current and future mission analysis work, as well as preliminary assessment of scientific opportunities presented by the Space Exploration Initiative and the technical trades that might be required.

The study identified several factors which directly impact program cost, regardless of reference approach used: mass to low-Earth orbit, technology payoffs, scale of lunar and Mars activity, availability of heavy-lift launch vehicles, nature of international participation, and funding stability. It also identified several critical technology challenges: closed loop life support systems, aerobraking, advanced space engines, surface nuclear power, in-situ resource utilization, and radiation protection. Although these technologies are critical, this list is by no means inclusive. There are additional technologies currently under development or planned for development which are absolutely essential for mission success.

Our work has just begun. We are continuing our mission studies and working to better define program elements and requirements. We are investing in new technologies and outlining an overall strategy for Space Exploration Initiative technology. In addition, we are supporting a number of outside reviews of our activities. As I will describe in more detail later, we are about to initiate an extensive outreach program to search for new ideas and new approaches to technology and mission concepts. We have identified a number of program areas within NASA which are essential for the ultimate success of the Space Exploration Initiative: Space Station Freedom, heavy-lift launch vehicles, robotic missions, life sciences research, technology development, science opportunities, and institutional requirements. I would like to briefly discuss each of these areas.

President Bush called Space Station Freedom "our critical next step in all our space endeavors." There we will perform extensive life sciences research and devise countermeasures for long-term microgravity and radiation exposure which are vital for long journeys to Mars. We will develop and validate the technologies we will use for future space missions and develop required operational procedures. Our studies also show that Space Station Freedom will very likely be necessary as a transportation node, where we will assemble, test, launch, recover, and turn around the space vehicles which we will use in our outward journeys. At the outset of the Space Station Freedom program, President Reagan stated that the facility would be international, useful for research, and permanently manned. NASA is committed to attaining these goals. This includes upholding our international agreements for Freedom and assuring its continued usefulness for research. OAET is working closely with the Space Station Freedom management to ensure Freedom's compatibility with these objectives and with future exploration requirements.

Heavy-lift launch vehicle development is another program area crucial to the Space Exploration Initiative. Our studies show that to establish a lunar outpost, an Earth-to-orbit lift capability of approximately 70 metric tons is required. This requirement increases to 140 metric tons for a Mars outpost. Vehicles currently being considered to meet these requirements include Shuttle-derived vehicles and the new Advanced Launch System (ALS). ALS is currently being defined in a joint effort by NASA and the Department of Defense. The design objectives of ALS --low cost per flight, high reliability, and high operability-- make it an attractive addition or alternative to Shuttle-derived vehicles. Vehicles of different sizes could be developed to meet the needs of lunar and/or Mars missions. Other options for space transportation may emerge as we continue our study efforts.

NASA is already planning for some of the robotic missions which are integral to the Space Exploration Initiative. Robotic missions serve a number of critical functions: determining suitable/desirable landing and outpost sites; providing design data for human mission elements; conducting science investigations; and developing the basis of science investigations for human explorers. Additional work planned by NASA's Office of Space Science and Applications (OSSA) for the Mars Observer in FY 1991 will allow more data to be retrieved in support of the Space Exploration Initiative. OSSA is also planning to begin Phase B of the Lunar Observer in FY 1991.

Life sciences research is particularly important for the Space Exploration Initiative, and we are working closely with OSSA which is responsible for NASA's life sciences program. To ensure that we can send humans to Mars confidently, research must be conducted in the following areas: effects of microgravity and countermeasures, radiation environment, medical care, life support, and behavior and performance. We will use Space Station Freedom, robotic missions, and eventually the lunar base to understand life sciences requirements in these areas and test methods to mitigate risks. Life sciences requirements must be understood early in the planning process since they can significantly affect vehicle and systems designs.

Major technology investments need to be made now to ensure success in these epic journeys. Some of these developments will reduce the mass required to be launched to low-Earth orbit and, therefore, associated time and money. Some are also indispensable for the establishment of relatively self-sufficient planetary outposts. Still other technologies are important because they could allow us to accomplish the goals of the Space Exploration Initiative better, safer, faster, and cheaper. We are currently working on a report requested by the Senate Appropriations Subcommittee on VA, HUD, and Independent Agencies on specific technologies needed to meet the development and operational requirements of the Space Exploration Initiative. We expect to issue this report this spring.

Taking advantage of the unique scientific opportunities presented by long-term occupation of lunar and Mars outposts requires significant planning both by NASA and the research community. Scientists in many disciplines, including solar physics, geology, biology, astrophysics, chemistry and space physics will find abundant opportunities for research and experimentation through the Space Exploration Initiative. A combination of robotic and manned missions will serve science well; robotic science missions will both perform vital and interesting science and serve as building blocks for the manned missions of the Initiative.

NASA's Office of Space Science and Applications (OSSA) has the responsibility for defining and, ultimately, implementing the scientific programs which will be an integral part of the Space Exploration Initiative. We are working closely with OSSA to ensure that accommodating scientific planning and requirements is a critical element of our technology and mission analysis efforts.

The FY 1991 request for Exploration Mission Studies is $37 million. We will use this funding to support a series of broad trade studies, missions studies, technology trades and analyses of science opportunities. Mission integration studies will be conducted in a variety of technical areas including: transportation, surface systems, power, propulsion, life support and robotics. The studies will be conducted in close coordination with our technology development efforts.

A variety of opportunities for international cooperation exist in both the robotic and manned portions of the Space Exploration Initiative. On March 30, 1990, the White House announced a strategy for exploring these opportunities. A dialogue focused on the conceptual possibilities for cooperation will be held with Europe, Canada, Japan, the Soviet Union and other nations as appropriate. The dialogue will be based on guidelines prepared by the National Space Council which are consistent with the National Space Policy and take due account of U.S. national security, foreign policy, scientific, and economic interests. The National Space Council will ensure interagency coordination and review during development of international cooperation on the Initiative, and will provide recommendations to the President as appropriate.

As you can see, the Space Exploration Initiative is a broad, bold program for space leadership which spans the breadth of NASA's programs. Much of our current effort is directed toward integrating the efforts of the various programs in space science, space flight, and technology as well as identifying a strategy for future progress. Most of the $15 million we received in FY 1990 for exploration is being spent on continuing the mission studies which have been ongoing for the past two years. A more recently defined activity for FY 1990 and beyond, one which will require a great deal of dedication and effort, is an extensive outreach program.

In December 1989, Vice President Quayle sent a letter to Admiral Truly asking NASA to take the lead in searching for and screening the broadest possible range of ideas about different architectures, new systems concepts, promising new technologies, and innovative uses of existing technologies. We want to ensure that all reasonable conceptual alternatives are evaluated and that the breadth of America's innovative and creative potential is drawn upon for the benefit of the Initiative. NASA has worked with the National Space Council staff and others to develop an outreach program for accomplishing this goal. We are planning a variety of activities to cast the widest possible net for new and innovative ideas which will include the involvement of industry, other Federal agencies and research facilities, technical societies and associations, and the university community in addition to our own continuing internal mission concept studies, science planning, and technology development efforts. The specific implementation plan for these outreach activities is in the final stages of refinement and we hope to proceed with this process in the near future.

NASA CAPABILITY

The programs that have been described above are critically dependent on the NASA institution, that is, the facilities and manpower that are required to conduct, manage, and support NASA's research and technology efforts. Maintaining our leadership in aeronautics and space requires an investment in people, the core of our capability. This is particularly true given the extended life-cycle of technology advances. A skilled in-house workforce must be maintained to see these advances progress from concept to implementation. Private sector contracting has been used extensively, with success, but not without certain drawbacks inherent in a contractor workforce. Our success in satisfying the unique and changing needs of our technology depends on a continuing strong human resource capability.

Without this institutional support, the research and development program outlined here cannot be conducted. It is imperative that the Wind Tunnel Revitalization Program and our facility maintenance augmentation be fully supported. It is also critical that the other facility additions and the institutional funding in the

Construction of Facilities and Research and Program Management budgets be supported.

The breadth of our "long-term, continuing commitment" to human exploration of space through the Space Exploration Initiative will undoubtedly generate new institutional requirements for NASA and, perhaps, other agencies as well. Our current institution, both manpower and facilities, is sufficient to begin work on the Space Exploration Initiative. We will be emphasizing an appropriate balance between in-house and contracted capability as we proceed.

INVESTING IN THE FUTURE

Our FY 1991 budget request is a critical step in realizing an exciting and challenging future in aeronautics and space and in expanding the frontiers of the future for the benefit of all Americans. Investment in technology represents a long-term strategic commitment to ensuring U.S. leadership. Investment in aeronautics and space R&T has played a fundamental role in achieving a leading role in the past and is the key to preeminence in the future.

Leadership in aeronautics is very important to our international balance of trade and national security and to the safety and efficiency of our air transportation infrastructure. We have a NASA strategy for maintaining technology leadership and, while we have made substantial progress in the past, much remains to be done. In partnership with U.S. industry, other government agencies, and the university community, we have prepared a roadmap and have defined priorities. We are aware of the tight budget environment and have requested only those high-payoff programs that are critical and timely. In FY 1991, we must strengthen our stewardship of the Nation's major Aeronautical test facilities, aggressively pursue those barrier technology issues that will allow U.S. industry to make informed decisions on high-speed aircraft, develop long-term solutions to support a healthy National Airspace System, and continue to pioneer the broad fundamental knowledge and technology base critical to the design of all future advanced aeronautical systems.

The ongoing NASA aeronautics research and technology program is conducting pioneering research in emerging technologies, selectively conducting the highest payoff systems technology programs, and producing technologies that industry can incorporate into future products. The results of our current research will be a major factor in our country's future aeronautical leadership. For 75 years, we have provided much of the technology base that has enabled the United States to be the world leader in aviation, but our task is not done. Today our leadership is being challenged on many fronts. The question is not whether we can afford to take on these challenges. The question is whether we can afford not to.

NASA is strongly behind the National Aero-Space Plane program. We are convinced that this program is crucial to U.S. aerospace preeminence and that it represents the very best in high-technology government/industry teamwork. It is a strong, soundly-based program, and NASA is proud to join with the DoD in this national effort in aerospace leadership.

NASA's Space Research and Technology program is well balanced and focused on the technology needs to enable and enhance our national space goals. The program supports vital basic research in technical disciplines, is structured to significantly enhance our near-term space missions and will lay the building blocks that will be the foundation for our future missions in space. Further, this program strongly contributes to assuring American strength in science and engineering by directing high payoff technical studies, providing and operating excellent research facilities and by setting vigorous and compelling technical goals and opportunities.

A key to future U.S. space leadership is the Space Exploration Initiative. Considerable preliminary planning is required to more fully understand the tasks ahead. Key technology programs are critical to success and require initial investment now. Vehicles and surface systems for these missions cannot be built until life sciences requirements are understood. No focused program plan has yet been agreed to, but now is the time to provide the initial resources to enable such a plan to be defined. The FY 1991 budget thus is an exciting opportunity to set our course as a spacefaring nation.

Thank you, Mr. Chairman. This concludes my prepared statement. I will be happy to answer any questions you may have.

Office of Aeronautics, Exploration and Technology

OAET

(R&D $,M)

	FY 1989	FY 1990	FY 1991
AERONAUTICS R&T	398.2	449.7	512.0
R&T BASE	309.6	326.1	353.4
SYSTEMS TECHNOLOGY	88.6	123.6	158.6
TRANSATMOSPHERIC R&T	69.4	59.0	119.0
SPACE R&T	285.9	285.9	495.9
R&T BASE	124.1	125.0	125.7
IN-SPACE TECH. EXPERIMENTS	-	10.2	19.8
CSTI PROGRAM	121.8	123.8	171.0
PATHFINDER PROGRAM	40.0	26.9	-
EXPLORATION TECH. PROGRAM	-	-	179.4
(PATHFINDER RUNOUT)			(91.4)
(EXPLORATION AUG.)			(88.0)
EXPLORATION MISS. STUDIES	(14.9)	(15.0)	37.0
TOTAL	753.5	794.6	1,163.9

90-1068

Responses to written questions submitted by Sen. Pressler resulting from the May 3, 1990, hearing.

Question 1: NASA conducts technological research into tilt-rotor and short-takeoff/vertical landing vehicles for future civil and military applications. What is the status of this effort? What is the relationship between the programs and DoD's V-22 (tilt-rotor) program and other similar advanced aircraft projects at DoD?

Answer 1: NASA remains committed to the development of tiltrotor technology. In FY 1990, approximately $5.0 million is being invested in high priority research and technology for tiltrotor vehicles. These resources are focused on barrier technology issues critical to improved vehicle performance with reduced noise and vibration. Close cooperation is maintained with the DoD and FAA, as well as the rotorcraft industry, to assure rapid technology transition for both military and civil applications. With DoD, NASA has performed high-speed performance validation of V-22 rotors in the 40X80-foot test section of the National Full-Scale Aerodynamic Complex (NFAC) at the Ames Research Center. NASA is conducting, with the US Navy, evaluation of a trailed tiltrotor concept in the Ames Research Center 7X10-foot Wind Tunnel.

NASA is cooperating with the FAA to study the potential of the civil tiltrotor for helping to relieve the increasing air transportation congestion problems. Public acceptance and infrastructure development are the next major hurdles for the introduction of a civil tiltrotor. The FAA has taken the government lead in addressing these issues and NASA is supporting and cooperating in these efforts through simulations, studies, and technical consulting.

NASA will continue to invest approximately $8.0 million per year for fundamental research for Short Take-Off and Vertical Landing (STOVL) aircraft. This research includes: CFD codes for application to complex flow fields where propulsion induced effects dominate the vehicle aerodynamics; developing control concepts and design criteria for the integration of flight and propulsion control; and rig tests of advanced development engines to evaluate bleed air flow requirements and to evaluate tolerance from hot gas reingestion.

NASA and DoD have been active partners in the planning and implementation of STOVL research and technology development . The DoD and NASA are cosignatories on the United States/United Kingdom Memorandum of Understanding for Advanced STOVL (ASTOVL), a collaborative effort to develop STOVL technology. The DoD, utilizing Nunn-Quayle resources, has supported NASA industry studies and is supplementing NASA resources to develop fundamental technologies and design methodologies. NASA is supporting DoD's STOVL requirements definition.

_Question 2: NASA and the Federal Aviation Administration (FAA) have been cooperating in a number of areas such as air traffic control, aging aircraft, and improvements in the pilot's display. What portion of the FY 1991 budget request is devoted to providing technological assistance to FAA, and what forms does that assistance take?

Answer 2: NASA and FAA have identified five major areas of cooperative R&T which have high payoff for aviation and the National Airspace System. These areas are: Cockpit/Air Traffic Control (ATC) Integration, Severe Weather, Airworthiness, Environmental Compatibility, and Human Factors. In addition, there are co-located FAA Engineering Field Offices at the NASA Ames and Langley Research Centers to facilitate cooperative research efforts. Executive level coordination and policy oversight is provided by the NASA/FAA Coordinating Committee which is co-chaired by the NASA Associate Administrator for Aeronautics, Exploration and Technology and the FAA Executive Director for Systems Development.

Major cooperative R&T efforts include ground and flight experiments in heavy rain effects, aircraft icing, and wind shear detection and avoidance. Simulator evaluations address flight crew and air traffic controller human factors concerns as well as integrate advanced precision navigation and aircraft scheduling technology with air traffic management algorithms. The highest payoff technologies are flight validated in airborne experiments and in a real world ATC environment. In the aging aircraft area, NASA is developing fatigue and fracture prediction methodologies and non-destructive inspection techniques to enable safe and cost-effective large-scale inspection of airliners. Related R&T that supports areas of FAA concern includes fundamental research in aircraft noise propagation and reduction, flight crucial systems, vehicle system studies, precision navigation, and simulations in support of certification criteria development. Major cooperative efforts and related R&T total approximately $27 million in FY 1991.

In addition, the High-Speed Research program is focused on answering the critical environmental concerns of sonic boom, emissions, and airport noise for future high-speed civil transports. The results of this research will help provide the FAA with a basis for rule making concerning the certification and operation of future high-speed aircraft. This program totals $44.0 million in FY 1991.

Question 3: What emphasis is being given to the development of nuclear power sources in space? What types of nuclear power sources are being developed? How will they be used in NASA's space missions? What are the safety risks associated with the use of nuclear power in space and how are such risks being addressed?

Answer 3: The Space Research and Technology program has an aggressive technology development effort in both nonnuclear and nuclear space power sources. The nonnuclear activities include fundamental efforts in photovoltaic cells, arrays, batteries, power conversion and power management technologies. The nuclear power activities include both reactor and isotope sources.

Several potential missions are being considered as part of the President's Space Exploration Initiative. The use of nuclear power sources is required to enable these missions. For an initial lunar base, a solar-based system will likely be used and NASA's Exploration Technology program is developing photovoltaic and regenerative fuel cell technologies for this application. However, as the mission evolves, base power requirements will increase and nuclear power systems will be required. For example, in the case of an expanded lunar base with power demands of 100KW or more, our studies have shown that because of the weight associated with the energy storage system required to provide power during the 14-day lunar night, the weight of a solar power system would be vastly greater than a nuclear system. For a mature base, this would result in a launch weight savings of over a million pounds. In other cases, such as a proposed Mars base or missions to the outer solar system where the availability of solar power is limited, the use of nuclear power is either very beneficial or required. The very-low solar intensity at the outer planets precludes the use of solar power for exploration at those distances.

A description of these and other power requirements for civil space missions was included in the enclosed January 1989 report to the Senate Committee on Commerce, Science and Transportation entitled, NASA's Need for Advanced Nuclear Power Sources. As the report indicates, we believe that the use of nuclear power is essential to the civilian space program and that future space nuclear reactors can be developed and used in a manner that ensures the public health and safety as well as protection of the environment. Current risk analyses conducted by the Department of Energy for a number of possible SP-100 missions, considering both the probability of malfunctions, and their potential consequences, estimate risks that are significantly less than one potential latent cancer death per mission. Prior to approving any nuclear power source for launch and operation, NASA will follow a rigid process which will comply with all appropriate United States safety recommendations, criteria, guidelines and standards to ensure public health and safety. This approach is wholly consistent with NASA's past and present practices regarding nuclear system development and operation.

Senator GORE. Thank you very much. Let me ask you a few questions first of all about the Moon-Mars mission. As you heard me say in my opening statement, I am concerned about how realistic it is to project the funding of this amount of money without adversely affecting the on-going space programs—the other programs in NASA. So let me start by asking you, what is the projected total cost of the Moon-Mars mission?

Mr. ALDRICH. We have already looked at various strategies of going to the Moon and Mars in our preliminary studies, and it is honest to say that we actually do not know how and in what form we would proceed to the Moon and on to Mars and therefore to give a specific cost of a specific program plan is really not possible today. That is one of the reasons the studies I mentioned I believe are appropriate. Clearly, the program will be in the hundreds of billions of dollars, but it will stretch over many years, and so as we evolve the strategies and program plans, the costing and the annual cost profiles would be part of what we would develop as we go forward in the next several years.

Senator GORE. Now, hundreds of millions, or hundreds of billions?

Mr. ALDRICH. Hundreds of billions of dollars.

Senator GORE. It will clearly be in the hundreds of billions. All right. In that same regard, what is NASA's expected time frame for returning man to the Moon and then traveling to Mars?

Mr. ALDRICH. We have looked at a variety of time frames in terms of possible scenarios. The only time frame we are really keying on relates to the President's initial challenge, which was return to the Moon. Finish Space Station Freedom in the 1990s, return to the Moon in the first decade of the next century and then on to the planet Mars with a manned mission.

There is a wide range of possible scenarios and time scales and technologies which really should, and need to be studied to develop the kind of program plan that would answer that question.

Senator GORE. Is it not true that you are basically shooting at the year 2000 to return to the Moon and go to Mars no later than 2016?

Mr. ALDRICH. In our budget request today, we truly are asking for money to understand and explore the time scales in the studies that we did last year. As part of our 90-day report, we looked at five mission alternatives which all focused on returning to the Moon between the year 2000 and the year 2010, and then going to Mars between the years 2016 and the year 2025, and so there is no specific target, and the Moon target that we have studied is somewhat later than the 2000 date you mentioned.

Senator GORE. What are the funding projections for the Moon/Mars mission in the next five years?

Mr. ALDRICH. Over the next five years? Well, let me say in this budget we have asked for $188 million and we are currently working a detailed budget for fiscal year 1992 and the several years beyond, and we have yet to propose and recommend such a budget.

Senator GORE. Can you give me a rough idea of what the funding projections are over the next five years? I mean, I am sure you have thought this through preliminarily.

Mr. **Aldrich**. It is on the order of $4 to $5 billion over the next—through 1996, but there are great variances in terms of what we might commit to in terms of these mission plans, and we may well evolve plans that could greatly change even the close-in profile.

Senator **Gore**. Roughly a billion dollars a year over the next five years?

Mr. **Aldrich**. It would start out smaller than that, and the studies that we would do would answer the questions whether to commit to significant increase in dollars in the years following 1992.

Senator **Gore**. But you really do not know?

Mr. **Aldrich**. We do not have a program to propose that we would fund in those subsequent years.

Senator **Gore**. Well, if there is no exact answer to questions on costs or scope or timing or content and the entire mission is still under review, why should the committee provide $188 million this year.

Mr. **Aldrich**. We need the money to do the review to have this complicated extensive set of missions and technologies and potential architectural options clearly thought through. We need to do the studies that would answer the questions that would lay out the scenarios and the requirements for making those missions possible without doing that work, this can only be a general debate and a program plan with meaningful content and hard recommendations cannot be brought forward in several years downstream.

Senator **Gore**. Is it unrealistic to ask you to think the project through enough so that you can give us a kind of a general projection of where you go in the first few years before we commit almost $200 million so that you can spent that money thinking it through?

Mr. **Aldrich**. I believe the right thing to do is to think through the longer scope of activity and begin some of the activities that are vital, no matter what the time frame and the mission scenarios are so that we can make really informed decisions downstream and to make those decisions we can bring several program options that are meaningful and have well developed content to base those decisions upon.

Senator **Gore**. Does it worry you that all of NASA's other programs will have to compete with this steadily growing expenditure for the Moon/Mars mission rising to several hundred billion dollars? Does it worry you that the other programs within NASA might be cannibalized?

Mr. **Aldrich**. The programs within NASA build on one another. The Space Shuttle is vital. The Space Station Freedom is important, and it is the right next step no matter where we go beyond and——

Senator **Gore**. I agree with that. I agree with that. But the point is, if you have a limited amount of money available for NASA overall and the programs you currently have underway are stretched to the limit of available funding and there is no realistic prospect for the administration to provide any realism or much less leadership on fiscal policy NASA will have to work with the limited pool of money. Then the prospect for cannibalization of existing programs in order to finance these massive expenditures on moon/Mars seems to be very real.

The constraints of Gramm-Rudman and the President's willingness to swear on a stack of Bibles that we do not need any structural reforms in spending or any tax increases, all that means that the size of Federal discretionary spending can be expected to decline in the coming years. And yet the President is calling for a program of hundreds of billions of dollars on top of existing programs and on top of the extremely important Earth Observing System. It just seems a little unrealistic for us to be talking about hundreds of billions of dollars in this context as funding allocations for NASA are pinched as seems likely. I hope it will not occur, but again, in the absence of presidential leadership on fiscal policy, it will occur.

Are there other programs in NASA that you would advocate reducing in order to make room for this new initiative?

Mr. ALDRICH. Well, let me return to the fiscal 1991 budget specifically, and I would like to repeat what Admiral Truly said when he talked about that budget, and that is this is one of the best balanced budgets that we believe we have ever brought forward, and I for one believe that some percentage of our budget should be based on planning the long range in the future and where to invest our technologies so that as we move forward, we know where we are going and we put in place what we need to allow us to move beyond.

This budget does that, and it asks for a very modest amount to start that process.

Senator GORE. How would you prioritize Moon/Mars compared to Space Station Freedom, the Space Shuttle, EOS and the other space science programs?

Mr. ALDRICH. I would say that as I said a minute ago that Space Station Freedom and the Space Shuttle are vital, and the EOS and the moon/Mars program built on those earlier programs. In terms of prioritization, they are all important programs, and they all play a different role both in terms of time frame and in goals for the future of our nation.

Senator GORE. You left the other space science projects out of there.

Mr. ALDRICH. Well, there are many other space science projects, probably too numerous for me to recollect here, but some are very imminent and are now flying and are about to fly and others are stretched out through the upcoming years. So, there is an extensive and robust space science program which the EOS is in addition to.

Senator GORE. Now, I heard your answer to have three categories. In the first category you placed the Space Station Freedom and the Space Shuttle. In the second category you placed EOS Moon and Mars. And in the third category you placed the other space science projects. Is that an accurate——

Mr. ALDRICH. I did not mean to place the other space science projects third.

Senator GORE. Okay, where would you put them in, the first or second category?

Mr. ALDRICH. I simply said that the transportation systems are vital, and they are critical to any of these other missions and, therefore, they must continue and they must be supported. I said that there is great value in each of the other programs we talked about, and their priorities should be considered, and within the balance of our budget each has been given an appropriate, we think, supporting role for this particular budget year.

Senator GORE. Recently, Mr. Robert Grady, Associate Director of OMB, who incidentally I respect a great deal. I think he is a very capable individual. But he gave an interview with "Space News", and he was asked to identify the sources of revenue which support the administration's proposal for NASA and the prospects of the huge new expenditures on the moon/Mars program. He gave a very candid response. He said that economic growth, in his opinion, will yield $83 billion of additional revenue in the next fiscal year. He said that he felt we could raise $13 billion by increased fees and cited as an example of higher rates for barges using the canals and ships. He assumes that interest rates are going down—it does not seem to be working out that way—and that this will allow us to retire some of the debt. He assumes a total of about $30 billion as a result of cuts in health care for the elderly and in agricultural programs. And he assumes increased income from a cut in the capital gains tax That is where he says the money is going to come from for this ambitious NASA program.

This is not in your area of responsibility to decide, but all of us on Capitol Hill and the administration have these conversations about where NASA goes from here in a context that makes much of the discussion wildly unrealistic. For us to be here this morning talking about several hundred billion dollars being allocated to a mission to Mars when the savings and loan scandal and the fiasco of mismanagement there is eating up every bit of the so-called peace dividend. And the President is still saying there is going to be no change on fiscal policy. I want to take some of the heat off of you because you are doing the best you can, and Admiral Truly is doing even better than that. All of you are working very hard down at NASA, and I respect what you are doing.

But I want to send a message to the administration that coming up here to sell a multi hundreds of billions of dollar new program without any indication of how it can be financed is a little unrealistic. It is a little unrealistic.

I think the administration before discussing a mission to Mars needs a mission to reality and some discussion of how they are going to come up with $500 billion. Really. Because otherwise—and again, it is not directed at you, Mr. Aldrich, but otherwise we have to contemplate that serious damage would be done to other initiatives within NASA by starting out small on a program that then rapidly grows to the hundreds of billions of dollars level. So I do want to make that point.

In your testimony you highlight several reasons for undertaking a manned missions to Mars and you talked about the intangible benefits of this exploration of the solar system. I happen to agree with that. Some people hear testimony like the statements you presented and think well, that is not good enough for hard-nosed people to allocate money on that. I happen to agree with a lot of what you say. I think that is a good reason. And the other reasons are very persuasive to me, but let us just try to pin it down a little bit for the record.

First of all, with respect to a return to the moon, we have already been to the moon. What is the primary reason for returning to the moon?

Mr. ALDRICH. We are not ready today to go to Mars. Mars is a very long mission. It has great uncertainties about humans in terms of their life support. There are systems we need which must operate for many months to go to Mars and back. By going next to the moon, we are able to develop the technologies and develop the systems and develop the ability to live in a remote area away from the earth in such a way that we will prepare ourselves to understand how to transition to Mars.

The moon is remote and yet it is close, and it provides us a very appropriate planetary-like body on which to do many of the activities that would be precursor activities to going to Mars.

I would also add that there are very significant science benefits from going back to the moon. There are benefits of using the moon as the next observing platform beyond our great observatories that we are putting in place during the nineties and, in fact, the back side of the moon is a very excellent place to build even larger scientific investigation equipment for looking out into the universe and beyond.

Many benefits from the moon. Probably the best one is that it allows us to prepare to go to Mars and understand many of the things that it will take to go there before we launch on such a lengthy and extended mission.

Senator GORE. What do you see as the primary justification for a manned mission to Mars?

Mr. ALDRICH. The manned mission to Mars is a goal. It is a goal that we can focus on and do many things that we otherwise might not drive ourselves to do in terms of developing technologies, developing capabilities and doing those things that are hard and driving us to reach forward and go out to a very significant challenge. In doing those things we will allow ourselves to go to Mars and derive the benefits from doing the work that creates the capability to go there. And when we arrive at Mars, we will be able to learn things about our solar system and probably about our planet earth that we otherwise would not be able to learn.

Senator GORE. Do you think it is unrealistic for us on Capitol Hill to ask how we are going to pay for it?

Mr. ALDRICH. I believe understanding how to pay for it is part of what I am talking about in terms of building a program plan. I am certainly not expert on government fiscal capabilities and capacity and decisions. I am fairly informed in terms of our space systems and our technologies, and I believe the right thing to do is to put in place enough information so we can see what the range of approaches are to deal with these strategies of going to the moon and going to Mars and the time frames we like to do them to.

A program of several hundred billion dollars is a very large program, but when it stretches over 25-30 years it does not result in incredible growth in the annual NASA budgets that would be required, and I think with the right attention to strategies and detail and more specific goals, we can build programs with important near-term milestones and also scenarios that play out over the years that are not only affordable, but that do have the benefits and other things that our country should be doing.

Senator GORE. Now, if we do not have a Moon/Mars mission and we simply continue the other programs in NASA already initiated, the EOS program, the Space Shuttle program, the Space Station Freedom, that will result in a steady increase in NASA's share of the budget over the next decade, correct?

Mr. ALDRICH. Yes. It will definitely increase NASA's budget over the next decade to do the things that we proposed, including EOS, which by the way I would not want to say anything to detract from. I think it is a highly appropriate and necessary program to focus on.

Senator GORE. Yes, I agree very strongly. The increase proposed by the administration for NASA this year has been, what, 21 percent?

Mr. ALDRICH. It is on the order of 21 percent.

Senator GORE. Without a Moon/Mars mission, what will be the projected increase in next year's budget for NASA just because of the normal program maturation in Space Station Freedom, EOS and the ongoing programs? What is projected?

Mr. ALDRICH. Well, we are building next year's budget, the 1992 budget now, and I am not privy to enough of the details.

[The following information was subsequently received for the record:]

The projected runout for FY 1992 of the FY 1991 budget request for NASA, without funding identified to support the Space Exploration Initiative is $17.0 billion. This represents a 12.5 percent increase over the FY 1991 request of $15.1 billion.

Senator GORE. Is it roughly another 20 percent increase on top of the one this year?

Mr. ALDRICH. I would honestly like to get that answer for you because I am not the most qualified person to say.

Senator GORE. Our analysis shows about another 15–20 percent increase will be needed just to fund the other programs without the Moon/Mars mission.

Now, the Federal interest expense on the deficit and, again, this is going above your area of responsibility, but we have to look at this context in order to judge the realism of the proposal you are making here today. The increased interest expense for financing the U.S. debt is—the annual increase is about $30 billion. Every part of the budget is under incredible pressure, and just to fund the ongoing programs before this initiative is presented, NASA has to anticipate an annual increase in its share of the budget of roughly 15–20 percent over the next several years.

Looking at that situation I do not understand how the administration can propose a $500 billion new start without any indication of how we are going to pay for it at all. None, except—well, let me retract that—increased fees for the use of canals by barges, cuts in health care for the elderly. These were the specifics offered by the Office of Management and Budget when they were asked the question.

I do not know. Maybe it is better just to play out the program and do the regular old authorization hearing and say yeah, we really like this, this is great, I support it, let us go ahead and do it.

I do support it. I think it is great. But I would like to see some indication of realism, as I say, before discussing a mission to Mars. The administration needs a mission to reality. Let us have some idea of how it is going to be financed.

But let me come back to the specifics that you are really here to discuss. Tell us for the record exactly why you think it is worth the massive expenditures to send human beings to the surface of Mars rather than robotic instruments which can collect most all of the knowledge that could be collected by human beings.

Mr. ALDRICH. Part of our initiative will require extensive use of robotic precursor missions to understand what we should do on Mars, where we should go, and how we should do it. The communication time to Mars, however, is about 45 minutes when you send a command to a robot or listen for it to tell you what it is doing. It takes 45 minutes to transit the distance back, which almost precludes direct control from the Earth of any robotic equipment. It has to be completely automated as it does its task.

I believe we will build good robots. We will do good science and exploration that way, but they will in no way replace what man will be able to do and find when we arrives at Mars and is able to do the kind of intense and careful investigation of the Martian body that this will enable.

Senator GORE. But as a precursor, we are going to send robots if this program is implemented, right?

Mr. ALDRICH. Our plan would be to send precursors both to sample the surface and also the map the potential areas of greatest opportunity for us to go to when we arrived with manned vehicles.

Senator GORE. The administration studied the choice between a mission to Mars and a mission back to the Moon, and ended up deciding that it could afford to do both. If you had to make a choice between a mission to Mars and a permanent Moon base, which would you choose?

Mr. ALDRICH. It is my opinion that we should go to the Moon first and if that is as far as we can go, then that is the way that scenario would play out. But I believe the benefits of going to the Moon for what we will learn and what we will develop and what we will understand about planetary exploration are necessary and important.

Senator GORE. Even though we have already done it?

Mr. ALDRICH. We have made short sprint to the Moon, gone down briefly, returned and not gone back, and that in no way relates to the kind of permanent base that we would talking about for the next century.

When we did the Apollo program, we did not go straight to the Moon, we did the Mercury and Gemini programs as precursors for experience and to learn how to do the things we would need to go to the Moon. And I believe in the human exploration initiative, the Moon phase of going back and learning how to exist there permanently provides the same kind of precursor understanding of the difficulties and the needs that the Mars program would now benefit from.

Senator GORE. How much of the proposed increase of $188 million for technology for the Moon/Mars mission could be justified for other reasons?

Mr. ALDRICH. The $188 million for—there are really two 188s in our budget. One is $188 million of new money for——

Senator GORE. Yes, this is the $190 million on technology.

Mr. ALDRICH. And within the technology budget there is a $179 million that relate to the technology work specifically for the human exploration initiative. It is a growth of our Pathfinder Program, which has been in place for several years, which has been funding precursor technology studies, and then the addition of the start of the actual exploration initiative itself and focusing on additional technologies to allow us to build a time schedule.

Senator GORE. Do you really get any new technology out of that $180 million or are you buying paper?

Mr. ALDRICH. You get new technology. We invest in things that, not in a single year's investment, but over several years as we mature these technologies, provide real things that would not otherwise be available.

Senator GORE. With such a massive undertaking there will be many who argue significant reforms are needed in current Federal procurement personnel and funding processes. Could a mission of this magnitude be accomplished within the existing framework of procurement personnel and budgetary processes?

Mr. ALDRICH. We would need augmentation in terms of our resources for personnel and facilities and that would be part of the plan that we would develop. In terms of the procurement process and some of the other regulatory controls that NASA faces, we have a team in another office under Admiral Truly that is looking at that situation, to make recommendations, in addition to the program recommendations which would come out of our efforts in my office.

Senator GORE. All right. Let me shift gears now to some of the other programs in this budget. I will just conclude my questions for you on the Moon/Mars mission by saying that I think the administration's program is unrealistic.

I support the goal of a mission to Mars, but I do not understand why the U.S. taxpayers have to foot the entire bill. I do not understand why we do not invite the Soviet Union and the European Space Agency and other space-faring nations to join in the initiative and in the funding of the initiative, emphasizing robotic exploration before setting a realistic timetable for human beings to walk on the surface of Mars.

In the middle of the Cold War, when the United States and the Soviet Union were locked in intense competition, the goal of sending men to the Moon and returning them safely within 10 years was not only inspirational, it made sense in a variety of ways.

The world is now changed. The Cold War is over. The United States has been joined in a new competition with Europe and Japan in the economy and it makes sense to have a shared program with a realistic timetable and a realistic estimate of how it came be financed.

That is my view on it. I think the overall goal is a good one, and I would like to work with the administration to see how we could come up with a realistic plan to achieve the goal. But this is not a realistic plan—$500 billion with no indication whatsoever as to how it is going to be financed.

It is not your fault. You have been asked to work out the details of a go-it-alone, Lone Ranger program as realistically as possible. You have asked for almost $200 million to get started on thinking the thing through. I understand where you are coming from, but I do think that it is unrealistic of the White House to take this point of view.

I have some questions in other areas. Before I ask those questions—I will come back and do it on the second round—I want to recognize my colleague, Senator Bryan for questions and a statement if he so desires.

Senator BRYAN. Thank you, Mr. Chairman. I was just able to join the discussion. Let me yield my time back to you and participate indirectly in the colloquy that you are having with the panel. And if I do have some questions upon what they develop later on I will ask to be recognized at that point, if I may.

Senator GORE. All right. Very good.

Let us move now to aeronautics. You stated that strong foreign competitors are capturing an increasing share of worldwide aviation markets. In your view what must be done by the United States to maintain its leadership position in aircraft manufacturing?

Mr. ALDRICH. We must continue to pursue the right technologies, to be sure that our vehicles and our capabilities are competitive and that we stay abreast of those developments which will be going on in other nations, both east and west.

Senator GORE. Are we making the investment necessary to maintain that leadership position?

Mr. ALDRICH. Yes, I believe we are. In this budget we have increases in our materials and structures program to pursue the competitiveness in those areas. We have an increase in the environmental considerations relating to the high speed civil transport program which is a precursor we believe to moving forward with the next generation of transport vehicles which the world will be growing into.

Senator GORE. Is the manufacturing industry doing its share of research?

Mr. ALDRICH. I believe the manufacturing industry is doing its share of research and are strongly connected with our government programs and vitally interested in our programs as well. They make significant use of the facilities I mentioned earlier as part of their internal research programs.

Senator GORE. When you say we are staying abreast of what others are doing, they used to dream of staying abreast with us. Are we struggling to stay abreast of what the foreign competition is doing in technology?

Mr. ALDRICH. Well, we are ahead in many areas still and by staying abreast I meant staying in that kind of relative position. However we have had losses in certain areas in terms of our technology and our products being preeminent in the world and particularly in the high speed civil transport area we want to pursue these technologies so that we will first and we will be the leader when those airplanes are built and when they start to serve our international markets.

Senator GORE. I will come back to this. I think Senator Bryan has a few questions, and I am going to turn it over to him for a few minutes.

Senator BRYAN. Thank you very much, Mr. Chairman.

Mr. Aldrich, this is an area that I have some very serious concerns and which we look to you and to others to provide some leadership. It is unmistakably clear to anyone who has a room temperature IQ that the Japanese are targeting aerospace as a new technology breakthrough for marketing in the global marketplace of the 1990s and the next century, just as they in previous decades have targeted automobiles and consumer electronics. And we all know that they have done an impressive job there. They have virtually destroyed the American consumer electronic manufacturing base and they have made some serious inroads in the American automotive manufacturing base, 26, 27, 28 percent of the market now.

Share with me, if you will, what is happening with respect to the hypersonic propulsion system. I read not too many weeks ago that the Japanese were trying to put together an international consortium, consisting of French government/private sector enterprise, Rolls Royce, several of the large Japanese manufacturers. They were also trying to invite the participation of Pratt & Whitney as I recall here in the United States.

Can you update me as to what has occurred or was the news report inaccurate?

Mr. ALDRICH. No, the news report is quite accurate as you described it. The Japanese have a targeted program for supersonic and hypersonic technologies for leading to transport aircraft, and their ministry of trade has recently announced a $350 million equivalent program, over about six years to develop technologies to support those areas. And they have put out bids for people to compete as part of that initiative and the companies and the countries you mentioned have participated in those bidding activities, including General Electric and Pratt & Whitney.

Senator BRYAN. Now has the consortium actually been formed or are they still just in the development stage of how they are going to put that package together?

Mr. ALDRICH. They are in the development stage of bid response and understanding what piece of what part of the work might be done by one or another, and those determinations are playing out.

Senator BRYAN. Mr. Aldrich, what should the American position be? I mean, Pratt & Whitney and GE are two fine American manufacturers that provide a great many of the engine systems, at least in the transport jets of today. To the extent that they participate in that if they are actually incorporated, what limitations are imposed upon them in terms of sharing any of the technology that they may be working on or developing with American manufacturers? Are they locked into some type of an agreement in which there is a control exercised primarily by the Japanese government as to who would have access and who would be able to make use of those technological breakthroughs?

Mr. ALDRICH. I believe it actually will work the other way. Both of those companies do technology work in those kinds of engine systems here in the United States for our programs and they have been keeping us informed of their discussions with this Japanese activity.

And in fact, whatever agreements might come out of this negotiation, it will be reviewed not only by NASA by other elements of the government for technology transfer and for other requirements to comply with the objectives of our government.

So I do not sense this as a technology threat at this point, but it does show an interest in these companies to stay with what is happening in their industry worldwide as these things evolve.

Senator **Bryan**. Mr. Aldrich, let me pursue that for a moment because I am not quite as reassured as maybe you would like to have me. Clearly we are involved in ongoing research. And indeed, if I am not mistaken does not either GE or Pratt & Whitney have a contract with the Federal Government to work on some of this technology?

Mr. **Aldrich**. They do. They both have contracts. They have contracts with NASA.

Senator **Bryan**. With NASA, okay. Now if they have contracts with NASA, and as a result of the money which the Federal Government and the American taxpayer is spending to participate in that research effort, to what extent are they then going to be allowed to participate in the Japanese consortium?

And how are we going to be able to determine whether it was on our nickel so to speak that some of these technological breakthroughs occurred, or whether if they are permitted to participate in the Japanese joint venture, that indeed the breakthroughs occurred as a result of that relationship?

Do we get any backspin from any of the technologies that may be developed as a consequence of their participation with the Japanese if that is to be permitted?

Mr. **Aldrich**. I cannot answer about the general transfer of technologies back from the Japanese, but the technologies that these companies developed with us will be protected under our technology transfer regulations and controls and I believe we will have open and understood dialogue leading to the decisions about what activities and contracts in fact would be put in place for the Japanese program.

Senator **Bryan**. So do we, Mr. Aldrich, under our present relationship or under the laws such as they exist, have the ability to say to a GE or a Pratt & Whitney, look, you are contracted with us, therefore you cannot, for national security or public policy reasons, participate in that consortium that is being proposed by the Japanese.

Mr. **Aldrich**. Well, it works the other way around. What they propose to do with the Japanese needs to be presented to our government, the Department of Commerce or Department of State and reviewed and accepted as complying with our international objectives and technology and on commercial interaction.

So their proposal would be understood at the appropriate time by the government and would be decided upon.

Senator **Bryan**. Just so I am not misunderstanding what you are saying, does the Japanese government then in effect present to the American Government, these are the objectives, this is what we contemplate in this research arrangement that we are involving all of these multinational or international concerns, and the American government then would have the ability to say, look, we choose not to allow participation?

Mr. **ALDRICH**. No, it would work the other way. Pratt & Whitney and GE would need to request clearance to do that work with a foreign country. And they would present what they have proposed to do, and it would be considered in the light of this discussion.

Senator **BRYAN**. I see. What do you think our position ought to be? I mean, I have some reason for these concerns. It seems to me you cannot serve two masters.

Mr. **ALDRICH**. There is a great amount of international teaming, not just in hypersonic vehicle work, but in all classes of aerospace work between countries and the United States and Europe and other nations, and it is going on at a variety of levels and each case I believe needs to be reviewed specifically for what it provides us as benefits and what it might pose in terms of our technology or competitive issues that we are concerned about.

Senator **BRYAN**. So you have not made a determination at this point?

Mr. **ALDRICH**. Well, certainly not on the specific one we are talking about and in other teaming relationship, some are ongoing today and are approved; others are contemplated.

Senator **BRYAN**. What is the time line? When are we going to have Pratt & Whitney or GE come to us and say, look, this is the proposed deal, take a look at it. Do we have any idea when——

Mr. **ALDRICH**. I think that is a function of the pace and the difficulties or progress that Japanese activity overall has. It has been playing out over some period of time and does not seem to be moving at a rapid rate at this point.

Senator **BRYAN**. What is the mechanism for making that determination? In other words, will those of us in the Congress be aware of the fact that Pratt & Whitney and GE now have a package together to be reviewed, to see whether they should be permitted to participate in this? Will there be any public dialogue on that or is that just something that is done in-house within the administration?

Mr. **ALDRICH**. I am sure there will be public dialogue. I am not sure of the specifics of how Congress will be informed, but I firmly believe that it will be widely understood and recognized as it plays out here within the government.

Senator **BRYAN**. We are not going to pick up the paper and read about this as a fait accompli some morning. There will be ample opportunities for some public input, congressional and otherwise.

Mr. **ALDRICH**. It is my understanding. My belief is that that is true.

Senator **BRYAN**. I think you came up with a figure of $350 million that the Japanese presently were investing?

Mr. **ALDRICH**. We understand that that is the amount that they project over a six- or eight-year period.

Senator **BRYAN**. Specifically, what are the parameters of the investment?

Mr. **ALDRICH**. Well, it is some of the things I was talking about earlier, it invests in the materials and engine capabilities and techniques that are required to support supersonic transport and up to the hypersonic range.

Senator Bryan. What are we investing?

Mr. Aldrich. Well, we have a significant investment in high speed civil transport that plays out over a number of years, and the stage that we are at in the fiscal 1991 budget is dealing with the environmental issues related to having such a transport before we move into developing the vehicle technologies, although some of our industrial firms are looking at a vehicle of that class. The technology to put the vehicle together in our plan follows studying what such a vehicle would do to the ozone layer and how we can preclude damage, studying supersonic boom issues, and airport noise-related issues so that if we elect to move out with such a transport, we will be able to do it in such a way that it is not an enemy to our environment.

Senator Bryan. I understand, and I think there has been a good bit of public commentary on some of the environmental concerns that we have about that. I do not disagree with that research being undertaken. But give us an apples-to-apples comparison. If we are focusing on the environment, and they seem to be focusing on the hard wire that maybe necessary to develop this kind of a system, how much are they spending and how are we spending in the hardware development phase as opposed to the environmental research aspect?

Mr. Aldrich. We are not doing hardware development currently. In this 1991 budget we are proposing to spend $44 million this year to do the work, to address these environmental issues, and if we are successful, we hope within the next several years to come in with a much bigger program to now start directly on the vehicle technologies that would allow us to proceed.

Senator Bryan. Mr. Rosen looked like he was trying to reach for the microphone. Mr. Rosen, my concern and the focus of my question is to try to get a sense of if they are spending a quantum of money to do what I call the hardware research, and there may be a better technical term, but in effect to determine whereas this thing fly, can it be put together, the materials, the structure, the propulsion system while we are spending $44 million for the environmental aspect. It seems to me that they may be gaining a considerable advantage, at least in terms of the developmental stage where we are focused on the environment. Maybe maybe that is not a correct perception, but I am sensing that maybe what is happening.

Mr. Rosen. Senator, there is in our budget request of $44 million. Most of that work is focused on making the next airplane environmentally compatible. Now, there are a couple of ways to do that. One is to understand the impact that that airplane would have on the environment. The other way and where most of the money is going in that budget request is on understanding how to make the hardware better so that in fact when you understand where we are today and what that would do to the environment, how do you alleviate those effects.

With respect, for instance, to ozone depletion which something that we are very concerned with, a significant effort is going into understanding how to make combusters that would produce enormously reduced quantities of NOX so that, in fact, the airplane would not impact the environment, the ozone in a negative way. That kind of research will be at the core, and that is almost a part of the engine.

We are trying to learn how to develop a core, a burner so that the overall engine that is built around it will be non- NOX-producing so there is a major portion of the work.

With respect to noise, we are looking at nozzles, and inlets and trying to understand how you can build a nozzle on such an engine that would greatly reduce the amount of noise. Now, those are hardware piece. Now, that is not going to be the hardware for the final engine, but it is the technology upon which the engine manufacturers will build their engines when it comes time to do so.

Senator BRYAN. You are saying, Mr. Rosen, you cannot design the engine until you understand the environmental aspects and what needs to be done to mitigate any negative impacts that it might have, as I understand?

Mr. ROSEN. That is right, and what the Japanese are doing with their $350 million, the major part of that is going towards engine technology and what I think they are trying to do is they are trying to catch up to us. They are trying to understand from where they are coming from now to get to the position that the United States engine manufacturers are in today, and they are spending an awful lot of money to build a 1/10 scale demonstrator engine. I think our manufacturers could do that rather easily, but that engine in either case will not be environmentally compatible, and so I think the kind of money that we are spending is and will keep us ahead of them as long as we keep doing this as long as we get our budget request approved.

Senator BRYAN. I appreciate the explanation, Mr. Rosen, but it still seems to me that we ought to be concerned if we are indeed ahead in some of these technologies, as you point out. I have some real reservation as to what extent we ought to permit participation by Pratt and Whitney and GE in this hypersonic consortium for the development of the propulsion system that the technologies which affect the American taxpayer in large part has helped to finance, together with the private sector. We do not want to just transfer that technology, it seems to me, to a potential competitor.

If there is one thing that we do enjoy a commanding lead in terms of our balance of payments problems, it is the export of aircraft. Boeing and McDonnell Douglas, we do very, very well in that. Those numbers work to our advantage. I do not like to see that change personally, and to the extent that we allow American participation in that system where taxpayer monies have helped to develop the advanced state of our technology, it seems to me we transfer to another.

That is one reason why a number of us in the Congress believe that the FSX is an unmitigated disaster. That the writing on the wall ought to be very, very clear as to where the Japanese are coming from. We have no one to blame but ourselves if we permit that to occur.

Mr. Chairman, in your absence we have had an interesting colloquy about where we are standing on the hypersonic transport development. Let me yield back to you now.

Senator GORE. Well, I have heard. It has been very interesting indeed. If I cover any of the same ground, please let me know and I will shift gears. But building on the dialogue you have just had, can a high speed aircraft be developed that will not emit nitrogen oxides into the stratospheric ozone layer?

Mr. ALDRICH. We do not know, and that is the program that we are investing in to try to understand how to preclude that kind of contamination in the atmosphere, and we are doing that up front before we start to build such a vehicle because a vehicle would not be of utility to us if it did the kind of damage to the atmosphere that we are discussing.

Senator GORE. Are the Japanese not doing that research? Are they going ahead without regard to the potential threat to the global environment?

Mr. ALDRICH. Well, as we discussed their program, they proposed a program that they are now formulating and building and getting people involved with, and so I do not think we know all the details of their program yet. I believe that they are doing is vesting both understanding the environment, but also moving forward towards investing in those systems that you need to build the airplane.

Senator GORE. Maybe they are just leaving it to us to pay for that research and merely using the Freedom of Information Act to get the information and concentrating on the hardware themselves. Is that what they are doing?

Mr. ALDRICH. Well, the Freedom of Information Act does allow much of our technology work to be available anywhere, and it is one of the reasons that our technology does flow so broadly around the world.

Senator GORE. But it is really not fair for them to ignore the environmental problems and go full speed ahead on the hardware if that is, in fact, what they are doing. Would a hydrogen burning vehicle like NASP be a commercially realistic venture?

Mr. ALDRICH. The NASP is definitely an experimental vehicle, and it is done for the purpose of evolving the technology that would allow later vehicles with objective goals to be developed. I think the NASP itself would not be an economically viable vehicle for use either for people or for cargo. We hope that one day vehicles of that type would be competitors economically.

Senator GORE. But it is really a military project?

Mr. ALDRICH. Well, it is done jointly with the DOD, but its purpose is single-stage orbit reusable vehicle.

Senator GORE. When you say jointly, it is done 90 percent by them and 10 percent by you, is that not right?

Mr. ALDRICH. Well, it is more like 70–30.

Senator GORE. Is it 70–30 now?

Mr. ALDRICH. Over a number of years that is the way we view the relation of the roles, but each year there have been various iterations of the budget. So by a single-year budget such as the one we are in currently, 1990, it comes out to be a different mix.

Senator GORE. Now, a hydrogen burning vehicle would not emit nitrogen oxides into the stratospheric ozone layer, correct?

Mr. ALDRICH. Well, as I understand it, the purpose of this vehicle is to be air breathing so you do not have to carry the oxidizers so you are breathing air and there is nitrogen involved and so there would be some potential for nitrogen oxide to come out of a NASP-type vehicle as well.

Senator GORE. But a NASP or a hydrogen burning vehicle would not have to be Mach 25. It could be Mach 6 or 7, correct?

Mr. ALDRICH. Well, the goal of the NASP is to go single stage to orbit, which means it has to go to Mach 22 or 23. To make it single stage means the same engine has to burn through the atmosphere and then be able to boost the final amount to get to orbit. A different class of hypersonic vehicle could be anything above Mach 5 and would have different objectives than single-stage to orbit.

Senator GORE. Speculate for a moment. If there is no way to limit the emission of nitrogen oxides into the stratospheric ozone layer, if you find that out, then would that lead you to stop the idea of such an aircraft entirely?

Mr. ALDRICH. Let me understand. Are you just talking about the NASP or the high speed civil transport?

Senator GORE. Any high speed craft which poses a significant threat to stratospheric ozone. I mean, we are in the midst of an agreed global crisis with respect to the stratospheric ozone layer. You accept that, do you not?

Mr. ALDRICH. Yes, I do.

Senator GORE. And the proposal for a new technology that would add significantly to the threat already posed has to be viewed within that context, does it not?

Mr. ALDRICH. Well, the reason I asked the question is that the direct objective of the high speed civil transport is to build many transport vehicles that are used commercially and used for people transport, and it would be unacceptable to have such a fleet of vehicles that would do any significant damage to the atmosphere.

The NASP vehicle is a research vehicle that would fly only a very few times, and there is not nearly the magnitude of threat for its emissions, at least early on. That would come from the other type of objective.

Senator GORE. Well, I personally think it is responsible to look first at these questions to see whether the threat can be managed or not. I am troubled by what the Japanese are doing, and I think that the Japanese may be underestimating what world public opinion will soon be. I think they are in danger of running into a brick wall.

Maybe we need an international ban on technologies that pose significant new threats to the stratospheric ozone layer and shift to an inherently clean fuel like hydrogen. Just focus the competition into boundaries that respect the global environment. Again, that is a policy question that will not be made in your office. But it seems to me that is something that ought to be actively considered.

I am prepared to shift gears to other subjects, but if you want to pursue this one——

Senator BRYAN. Mr. Chairman, if I could just ask a couple of questions that were raised during your exchange with Mr. Aldrich. The Freedom of Information Act, you have indicated that a good bit of the technology that is developed here is made available to virtually anyone pursuant to the Freedom of Information Act. My question to you is are there mechanisms in the law, as it presently exists, to say that this is technology that we as a country have a proprietary interest in and we ought not just to share that and make that available for either national security reasons or in terms of economic security reasons? Are there such provisions?

Mr. **Aldrich**. Well, there currently are not. However, we have that under serious consideration within NASA right now. If there are ways that we could in fact propose to change the Freedom of Information Act so that it could protect some of these things that we are concerned about, and we are also looking at a process, perhaps, for having different arrangements in our contracts where we allow proprietary rights for technology to remain with industry and therefore not become part of the public domain. But, again, we do not have a proposal here today, but are seriously considering these things.

Senator **Bryan**. Mr. Aldrich, I just hope you folks would be very, very aggressive. It makes absolutely no sense at all in this highly competitive world in which we live, and the more competitive world which we are going to live in the future, for us to make major scientific breakthroughs that clearly have commercial application and on which there is an enormous investment of public resources which we then give to our foreign competitors. I think there is a role for Federal participation in these projects to in effect underwrite those tremendous expenses in part by the American taxpayer. But it makes no sense to them say well, yes, under the Freedom of Information Act once we have achieved these breakthroughs, now, look, anybody out there has a right to get it free. That just does not make sense.

I recognize that there are some overriding policy considerations for the Freedom of Information Act. I would respectfully suggest to you that nobody contemplated at the time that this was developed to make American technology available to the world with potentially adverse implications for those of us who will hope to see America stay in the lead in some of these areas. So I would hope that at the appropriate time that internally you would develop such a thing, and if it requires legislation that you bring it to the Congress' attention.

I think that there are a lot of folks on both sides of the aisle who would be very, very interested in working with you in protecting that technology. I thank you, Mr. Chairman.

Senator **Gore**. Thank you very much, Senator Bryan. A couple of more questions. Briefly on the national aerospace plane, you have requested $119 million this year in fiscal year 1991 for the national aerospace plane project, double the amount appropriated for the current year. Yet, at the very same time, the DOD budget calls for a reduction of funding for NASP from $195 million to $158 million.

How high of a priority is the national aerospace plane for NASA?

Mr. **Aldrich**. It is a high priority for NASA.

Senator **Gore**. Do you have any low priorities?

Mr. **Aldrich**. Not in this particular budget. We worked hard.

Senator **Gore**. Do you have them in any budgets?

Mr. **Aldrich**. Let me say about the national aerospace plane I believe it is the most challenging aerospace technological project in the world today, and it is a vitally focused technology for us to pursue, and I believe it is a very important program.

Senator GORE. Well, what mission requirements does NASA have for NASP?

Mr. ALDRICH. NASA has NASP as a technology vehicle to develop the capabilities to fly at hypersonic speeds and go single stage to orbit. There is not a mission for the X30 NASP experimental vehicle itself.

Senator GORE. Does DOD have any mission requirements for it?

Mr. ALDRICH. No. It is the same situation.

Senator GORE. Does it have any role in the proposed Moon/Mars Mission?

Mr. ALDRICH. It could, depending upon how the scenarios I discussed might play out with time. We will need new launch vehicles, both manned and unmanned, and the NASP well could be the kind of vehicle that would make sense for human cargo and other critical cargo in the next century.

Senator GORE. Now do you expect the trend this budget year to continue with NASA steadily picking up a higher percentage of the cost and DOD steadily decreasing its share in the cost?

Mr. ALDRICH. No. In fact, we will return to smaller percentages. One of the reasons this year for an increase for us and a decrease for DOD is that last year's budget, the 1990 budget, was adjusted so that the DOD ended up with a quite significantly larger share of the budget as it played out.

Senator GORE. Now while we are focusing on this, the Japanese and the Germans are looking at hypersonic craft Mach 7 and up. Why do you suppose they are doing that?

Mr. ALDRICH. They are looking at vehicles in ways similar to ours, and I am going to ask Dr. Rosen to comment on this, also, because he may have some other knowledge about it.

The Japanese and the Germans have been looking at vehicles that are two stage to orbit but yet they are reusable, more effective and more efficient vehicles to orbit than the kind of vehicles that are used today. We have chosen a more difficult task, which is a vehicle that goes single stage to orbit.

That is why I said I think ours is the most significant technological challenge that is being worked on.

Senator GORE. Mr. Rosen, are the Japanese and Germans looking at hypersonic craft in the Mach 7 range?

Mr. ROSEN. That is right, Senator. They are.

Senator GORE. We are not?

Mr. ROSEN. We are looking at Mach 7 and up.

Senator GORE. We are really focusing on the Mach 25?

Mr. ROSEN. Yes, but in order to go Mach 25 you have to go Mach 7. The technologies we are trying to do are much more difficult.

Senator GORE. That is right, but the Japanese and the Germans are looking at the commercial market; right? That is why they are looking at the Mach 7?

Mr. ROSEN. I do not believe that the German vehicle is a commercial vehicle at all. It is a way of achieving orbit for them. What we are trying to do——

Senator GORE. You do not think they are focused on the next stage in commercial transport technology with these projects?

Mr. ROSEN. They are looking for new and different ways to achieve orbit, and that is one. That is right.

Mr. ALDRICH. We think when you go above Mach 3 you get into different fuels which are much more difficult to make commercially plausible; and also when you get above Mach 3 the distances on earth do not as much provide the benefits to justify the expense that the vehicles pose.

So we think the high speed civil transport is the target that internationally will be pursued for the next vehicle, and that is one that both the Japanese and we are working up to working on.

Senator GORE. All right.

Let me go to the high performance computing program. At its last markup the Commerce Committee unanimously approved S. 1067, the National High Performance Computing Act of 1990 to keep our country at the leading edge in supercomputing and high speed computer networking. That bill authorized $22 million to NASA for fiscal year 1991 and a total of $338 million over the next five years to NASA for research and development on supercomputing in specific areas. This money would be in addition to that already being spent at NASA in this area.

The bill parallels efforts by the White House Office of Science and Technology Policy to develop a governmentwide supercomputing research program.

What has NASA's role been in the OSTP effort?

Mr. ALDRICH. We worked aggressively with the OSTP over the last several years to put together a multi-agency high performance computing initiative, and that plan is essentially complete. We will be bringing it forward, we hope, in this coming budget for 1992.

It is a very high priority focus program of OSTP, and we have been working very actively with the other agencies on that goal.

Senator GORE. How does NASA use supercomputing and high speed networking?

Mr. ALDRICH. We use supercomputing extensively for our aeronautics research and our space technology research. We use networking to be able to use the supercomputing nationally from our various research centers to our primary supercomputer site at the Ames Research Center in California.

Senator GORE. What data flows do you now have in and out of Ames?

Mr. ALDRICH. I guess I cannot answer that in a definitive way. I would like to answer that for the record, if I could.

Senator GORE. That would be fine.

[The following information was subsequently received for the record:]

The primary supercomputer network at NASA Ames Research Center is NASnet. NASnet connects the Numerical Aerodynamic Simulation (NAS) Program Facility, a complex of supercomputers at Amex, to 31 remote sites across the United States. The remote sites include aerospace industry, universities, and other NASA centers. In April 1990, 8.1 billion bytes of information were received at NAS and 33.9 billion bytes were transmitted from NAS across to NASnet. The information typically consists of solutions to aerospace problems that can only be solved using the power of the most advanced supercomputers.

I understand that for the last two fiscal years NASA has requested $20 million for a high performance computing program. What would that have entailed, and why did OMB turn down your requests?

Mr. ALDRICH. That would have entailed additional focus work on particularly a software techniques and software algorithms as part a total high performance computing initiative.

The reason that request did not come forward is because the timing of the total computer initiative with the other agencies and the other pieces of the initiative did not converge in such a way that the administration could present it last year. We have, however, several million dollars in our budget that was retained both in 1990 and 1991 to pursue our part of that work, and we believe across our total program there is some $50 million in the 1990 budget that relates directly to applications and processes that would be part of a high speed computing goal.

Senator GORE. Shifting gears again, there is a major ongoing debate in the administration about the role of the Federal Government in promoting high technology. Less than two weeks ago the director of DARPA was reassigned because of his vigorous efforts to expand the technology base on which our national security depends. Apparently there are some in the administration who wanted nothing in any way, shape or form resembles what they believe is "industrial policy".

Does this ideology apply to NASA also, or will NASA play the role DARPA has played in the past, identifying and funding research on particularly promising new technologies?

Mr. ALDRICH. I do not really want to comment exactly on DARPA's policies because I have only read the same articles that perhaps you are referring to, but I believe NASA is a great stimulant for technology that supports our industry, but the way we do that both in our aeronautics and in our space program is to focus on beneficial goals for vehicles or for classes of missions and then pursue the technologies that will enable those goals.

Senator GORE. You do not use off-the-shelf, tried and true approaches and rely on the marketplace to bubble up what you need in response to supply and demand?

Mr. ALDRICH. No, we do not. We focus on technologies that will enable these capabilities and missions, and by spending and executing these technological efforts we generate technology spinoff which is directly available to industry and which benefits them, I believe, in a very positive manner.

Senator GORE. Well, it is a sensible approach in the world of the 1990s, and it is for DARPA, also; but the administration does not think so apparently.

In any event, we are going to have to move on. I appreciate your appearance here today very much.

I want to emphasize again my comments that the fiscal context in which this discussion of Moon/Mars takes places is in no way a reflection of the subcommittee's unease with management of NASA but, rather, an effort to send a message to the administration that those of us who support an expanded program to explore the solar system will have tremendous difficulty in supporting the administration's initiative unless the President begins to offer some leadership.

The tried and true pattern he has established of promising a pie-in-the-sky proposal and then being nowhere to be found when it comes time to recommend a hard choice of any kind of how to pay for it will be fatal to a $500 billion program like this unless he changes the pattern and offers some leadership. It is best to make that clear right up front because anybody who thinks that NASA is going to get a steady 15 to 20 percent increase in its budgets year after year after year in this fiscal environment and then on top of that begin spending $500 billion to go to Mars is just nuts. I mean, the President is going to have to offer some leadership and begin to focus less on the popularity polls and a little bit more on the realism about our choices if he wants to really see this thing happen.

That is above your pay grade, as they say. We appreciate the job you are doing on fleshing out the details within the context you have given, and we thank you for coming here today.

Mr. ALDRICH. Thank you, Mr. Chairman.

Senator GORE. Our next panel is now invited to come forward: Lt. Gen. Thomas P. Stafford, U.S. Air Force, Retired, vice chairman of Stafford, Burke, and Hecker, Incorporated; Dr. John Logsdon, director of the space policy institute at George Washington University; and Mr. James C. Harrington, vice president for flight programs at Kaman Aerospace Corporation, representing the Aerospace Industries Association.

We are delighted that all three of you are here. Without objection, your prepared statements along with that of Mr. Aldrich will be included in the record in full. We invite you to present a summary of your remarks if you can, please.

We will begin, General Stafford, with you.

Welcome to all of you, and we look forward to your statements.

STATEMENT OF LT. GEN. THOMAS P. STAFFORD, USAF (RETIRED), VICE CHAIRMAN, STAFFORD, BURKE, AND HECKER, INC., ALEXANDRIA, VA

General STAFFORD. Mr. Chairman, I am pleased to respond to your invitation to discuss the National Research Council review of the NASA 90-day study on the President's goal to return to the Moon and go on to Mars. It is submitted for the record, and I will just briefly discuss some of the highlights of it, sir.

We reviewed under the guidance of Vice President Quayle and his status as the Chairman of the National Space Council the widest aspects of the approaches that NASA put forward in that study, the cost estimates on it, if the assumptions were reasonable and alternative ways to reduce risks and costs. The group was headed by Dr. Stever, and we decided at the end of our study effort that the referenced missions really were variations on a common theme and that they were built on some proven concepts with methodical research.

We also concluded that the eventual choice of the architect would incorporate a variety of ideas that exist now and some in the future.

One thing that we did go over in great detail was the need to advance the national space transportation capabilities. For this we must rely on the space shuttle for the next ten years or more, and we should maintain the space shuttle system.

We also concluded that NASA should go with procurement on a fifth orbiter to have a satisfactory operating fleet to the year 2000 and beyond and that there was a requirement to develop a new heavy lift launch vehicle, probably one that would be modular in effect.

One area of technology we identified to give us a high ratio of payoff could be a nuclear thermal rocket, particularly on a mission to Mars. For a Mars mission it could reduce the travel time by as much as 60 or 70 percent, which could be a good payoff.

Also recognizing the rapidly changing world and international cooperation, we called for a detailed assessment of potentially international cooperation with other countries in both returning to the Moon and going on to Mars.

We identified the fact that it was required for NASA to still maintain a very vigorous civil program, the unmanned planetary exploration, the earth remote sensing, the aeronautical research, which has been discussed earlier this morning in the testimony that Mr. Aldrich gave, to see that the country does have the capability to develop the SEI program based upon the resources and capability in the past. It is all detailed in a book that your staff has, sir.

Also, with respect to the letter of invitation, some other aspects discussed were why we should go there and to discuss possibly our thoughts on the political, economic, environmental, and educational considerations of this.

To start with, I think the SEI does have the potential, Mr. Chairman, for productivity and a positive relationship between government, industry and academia. This was really a good functioning productive area we had during Apollo which I participated in to a great degree.

Also in education it is hoped that it will stimulate education, particularly science and technology. In the past when we had the technical crisis on Sputnik, this was a motivating factor to the universities and the high schools. The same thing occurred during Apollo when there was a great interchange between NASA and the universities, and we can see it in the future.

I know that when on occasion I make a speech to a school, particularly younger students, and I ask how many of you would like to be an astronaut, most of them hold up their hands. If I ask how many of you would like to go to Mars, you still see most of them holding up their hands. You would hope that you could keep this motivational factor going for students all the way through high school and into college.

In world cooperation——

Senator GORE. Excuse me. Did you just use the term "SEI"?

General STAFFORD. Yes, sir.

Senator GORE. I thought this was a human exploration initiative.

General STAFFORD. Right, and in the latest definition, sir, to my knowledge, NASA has said this is SEI.

Senator GORE. I hope not, because there have been wide discussions of SEI in a completely different context as the Strategic Environment Initiative. It has been debated internationally. It has been used extensively in that context.

The human exploration initiative or HEI was discussed for a while I think it is very confusing for NASA to suddenly shift gears and adopt a set of initials that have already been identified in the public's mind in a different context altogether. I hope that NASA will reconsider that.

Go ahead.

General STAFFORD. The study we did, Mr. Chairman, was stated on HEI, and just recently I understood that NASA changed the terminology, and I will refer that back to NASA.

Senator GORE. It was not NASA, it was the White House. The White House asked NASA to change the initials. I do not know why they did that, but I hope they will reconsider and go with what NASA really wants to do instead of confusing the public debate with people talking about SEI and meaning one thing and then talking about SEI and meaning something else. It is just an unnecessary complication.

Excuse me. Go ahead.

General STAFFORD. In the area of international cooperation, that could be potentially one of the great cooperations in peacetime that the world has seen. I know that with respect to the Soviet Union there have been two efforts we have had over the past history when we cooperated together. One was World War II, and the other was the Apollo-Soyuz test program. I was the commander of the Apollo on my fourth mission in space for that one, and it was a very positive thing.

Again, we outlined in our review of the report that international cooperation should definitely be outlined and encouraged.

Finally, there could be a commercialization of the technology that would be there from the HEI, Mr. Chairman.

[The statement follows:]

Human Exploration of Space
A Review of NASA's 90-Day Study and Alternatives
by an ad hoc Committee of the National Research Council

Testimony by Lt. General Thomas P. Stafford
before the U.S. Senate Subcommittee on
Science, Technology and Space
Committee on Commerce, Science and Transportation

Mr. Chairman and Members of the Subcommittee:

I am pleased to respond to your invitation to discuss the recent NRC report on the NASA 90-Day Study. Last December, Vice President Dan Quayle, in his capacity as Chairman of the National Space Council, requested that the NRC examine the scope and content of the 90-Day Study, including:

- whether it addressed the widest possible range of technically credible approaches,
- likely areas for technical breakthroughs relevant to space exploration,
- infrastructure considerations,
- whether the 90-day report overlooked innovative uses of existing technology,
- whether the cost estimates and schedule assumptions are reasonable,
- whether there are alternate ways to reduce costs, improve performance, reduce risks, or move the overall schedule forward, and
- whether the overall approaches and architectures described in the report were reasonable.

Our study group was headed by Dr. H. Guyford Stever, and I'd like to attach the full committee list to the record of my remarks. The committee held a preliminary planning meeting, exchanged advance study materials, then met for four-and-a-half days in mid-January. We had the opportunity then to discuss the details of the 90-

Day Report with NASA's top leadership and technical experts. In addition, we examined several other possible mission architectures and Earth-to-orbit transportation systems.

In short, we concluded that the five reference missions discussed by NASA were "variations on a common theme," and that, "the mission concepts in the NASA 90-Day Report prudently build on proven concepts and methodical research, development, and demonstration of new technology. The concepts are comprehensive and robust."

We also concluded that it appears likely that the eventual choice of mission architecture will incorporate the ideas from a variety of concepts, some that now exist and others that will arise in the future.

Taking the 90-Day Study as a starting point, we continued on to discuss what we saw as important enhancements to it.

For example, there are some unanswered questions concerning the feasibility of long-duration human spaceflight in low gravity. The Soviet Union has had several cosmonauts spend approximately one year in space and recovered after a short time period. In addition to a continuing program on the effects of microgravity and the various countermeasures, we believe it is prudent to begin to develop the technologies for artificial gravity. We are also convinced that a stronger emphasis on advanced human/machine systems can enhance the productivity of humans in space and increase their safety. This effort may have a spinoff benefit of enhancing human productivity on human/machine interfaces on the Earth.

Second to the need for scientific research and technology development to support humans in space, is the need to advance national space transportation capabilities. While we must rely on the shuttle system for at least 10 years or more (and should continue to scrupulously maintain it), we also concluded that NASA should start procurement on a fifth orbiter to maintain a satisfactorily operating fleet. The committee saw the need for a new generation of liquid bi-propellant heavylift launch vehicles to transport massive cargoes to low Earth orbit. (Such liquid bipropellents can be tested prior to launch, unlike solid motors; avoid the pollution of the atmosphere associated with solids; and are potentially more reliable and less expensive.) In addition to new heavylift capabilities, a smaller, highly reliable carrier will be needed to transport humans and other high value cargo to orbit.

We are convinced that nuclear rocket propulsion can make an important contribution to the Space Exploration Initiative if it proves feasible and safe and can gain public acceptance. For example, a nuclear thermal rocket can reduce the travel time to Mars by 60-70%. To meet the heavy demands for electrical power on the Moon and Mars, nuclear electric power eventually will be essential.

Recognizing the rapidly changing climate for international cooperation, we called for a detailed assessment of the opportunities for international cooperation, as well as of the means to satisfactorily address technical and institutional barriers. Reflecting on the space station and other collaborative experiences, we concluded that enabling agreements should be supported at the highest levels possible within the participating governments and that detailed technical agreements should not be finalized before all parties understand and agree on the requirements for the Space Exploration Initiative and missions associated with it.

We believe that in addition to a program for human exploration of space, a vigorous base of civil space programs must continue to exist--including unmanned space science, Earth remote sensing, support for commercialization initiatives, and aeronautical research and development.

By any measure, the Space Exploration Initiative will represent a major commitment. However, accurate cost estimates are only possible where experience with the technologies exists. Currently, the necessary technologies and the SEI architectures are not completely understood. If space exploration is to be undertaken successfully, there is a clear need for a unique long-term commitment by successive Administrations and the Congress. In the next few years, we believe it may be useful to think about costs in terms of the level of effort that is both reasonable for making progress toward the SEI goals, and sustainable as a commitment of national resources.

Last, the nation is at an early stage in the development of the SEI. None of the analyses to date--the NASA 90-Day Report, our report, or other concepts--should be regarded as forming anything other than a framework for further discussion and innovation.

Senator GORE. Thank you. I remember watching that mission with rapt attention. That was so inspiring. Of all the space missions that people look back on in the history of our space program, the moon landing and that one which you headed are really ones that stand out in the minds of so many Americans. It really was a job well done.

General STAFFORD. Thank you, Mr. Chairman. It was a lot of fun to fly, too, sir.

Senator GORE. Dr. Logsdon, we will go to you next. We are going to get you out of here on time. I am told you have an obligation elsewhere, so we will move right along and make sure that we get questions to you first if we start running short on time.

STATEMENT OF DR. JOHN M. LOGSDON, DIRECTOR, SPACE POLICY INSTITUTE, GEORGE WASHINGTON UNIVERSITY

Dr. LOGSDON. Thank you, Mr. Chairman. I do have myself covered if you want to continue the discussion.

From the perspective of spending 20 years of a career tracing the history of the U.S. space program, I can make the observation that we are indeed at an unprecedented juncture in the evolution of that program. The opportunity to set a productive path for the future has never been greater. Seizing that opportunity requires some vision and some risk taking.

In my view, the opportunity is not likely to last very long or reappear soon. For those of us, of which I think you are one, who believe that space exploration should be an important part of the U.S. agenda for the 21st Century, it would be tragic if the opportunity were missed.

Indeed, never before has a U.S. president proposed to Americans that they make and sustain a national commitment to human exploration of the solar system. President Kennedy in 1961 asked his advisers to find him a space program "which promised dramatic results in which we could win." That led to Project Apollo. It led to a race to the Moon and not to a commitment to exploring the solar system. It was basically a demonstration of American power both to the world and to ourselves.

In the two decades since that demonstration took place, the central theme, the cry of those concerned with the vitality and integrity of the American space program is the need for a coherent long-range purpose against which specific policies and programs could be evaluated. This need has been seen, I think, particularly in that portion of the program with the highest cost and the broadest public interest, human space flight.

For example, in 1984 the Congress mandated a National Commission on Space to chart America's future in space. Now President Bush has embraced the vision put forth by that commission. For the first time an American president has put forth exploration of space as something worth doing in its own right. Mr. Bush did not claim economic or military payoffs from a return to the moon or a voyage to Mars. He justifies such undertakings "because it's humanity's destiny to strive, to seek, to find."

Now I think we should be a little bit cautious with the use of the word "destiny". I do not think it means inevitability or an imperative. Rather, it should be understood as the result of making specific choices within the overall flow of events and trends. Humanity can help create its destiny through the choices made by individuals and societies at particular times. For space, I think that time is now.

I think that is the level of what has become known—and I have Space Exploration Initiative down here rather than Human Exploration Initiative, also, so I will just call it Exploration Initiative for the time being—should be debated, not at the level of specific budgets or particular programs.

I think Mr. Bush's speech last July and the activities that have gone under Space Council and NASA leadership since then should be viewed just as a starting point in a national discussion of whether this country agrees that 21st Century America should be a leader in space exploration.

President Kennedy, when he spoke to Congress in May of 1961, said that "this is a choice that the country must make," and I think those words apply equally well to today's situation. There needs to be several years of debate within Congress and throughout the country before a commitment to human exploration and expansion is made, but that debate has to start, not be prematurely foreclosed.

This is my reading of the intent of the Presidential decision of March 8 on program strategy, that says for the next couple of years invest in technology and look at alternative approaches before committing to anything, and the decision of March 30 to start an exploratory dialogue with the Soviet Union, Europe, Japan, Canada and other countries for potential cooperation.

I think it is also the intent of NASA's plans as outlined this morning by Arnie Aldrich. Congress is not being asked now to make a long-term commitment but, rather, to make possible the actions essential to informed choices several years from now.

Let me draw a parallel, which is not in my written testimony, to the EOS program, which you strongly support. That program is a new start in the fiscal year 1991 budget. We have been investing in that program for almost a decade in preliminary research, in advanced technology, in mission studies and in involving the concerned community. You have a coherent, well thought out proposal before the Congress now. It seems to me it is the same sort of investment that is being talked about now with the Exploration Initiative, not a commitment to a particular plan, budget, schedule, or anything else.

To say that we cannot afford to or should not now begin this process of shaping a productive long range purpose for humans in space seems to me to be defaulting on our responsibility to the future. Yet, the reaction to the initiative from many in Congress and the aerospace industry and, indeed, from many within NASA has been strangely unenthusiastic. Many seem unconvinced that President Bush is serious. They appear unwilling to risk already approved programs and their established positions of power by linking them to support of the long range goal of human exploration.

There is, I think, an ownership issue here. Space policy for over two decades has been the domain of a very specialized issue network. Now it is being formulated by the White House and by the Space Council. The former custodians of the space arena are having some problems, in my view, adjusting to this new reality. NASA is being challenged to improve on past performance, and no agency enjoys that kind of public pressure and criticism.

I do think that Admiral Truly believes the President's words and is committed to reforming NASA, so that it regains all of its reputation, and maybe more, for technical and managerial excellence and integrity. I think he and his associates need a signal from leaders in Congress that his efforts in making the necessary changes and in setting new directions will receive their support as well as White House support.

More fundamentally, the skeptics in the aerospace community need to be convinced that there is adequate political will in both the White House and the Congress to set a broader course for current space activities. I think leadership is required at both ends of Pennsylvania Avenue.

We are, in my view, already engaged in a multi-billion dollar Exploration Initiative. I think we need to acknowledge that reality in order to provide a context for current programs and in particular space station Freedom. The space station program, life science research, investments in new technology, and future choices in space transportation would all profit from being recognized as part of humanity's outward movement.

I suggested a few minutes ago that there is now an unprecedented opportunity to set a productive path for future U.S. efforts in space, but that opportunity, stemming from—finally—a presidential willingness to lead the country in space, will not last forever. The President and his associates could become convinced that the space community will not or cannot deliver the kind of program they are calling for.

There are certainly many other claimants for the kind of priority that the President has so far assigned to space, but the space community cannot seize this opportunity without Congressional as well as presidential support. That support and some modest actions to back it up is what I hope you and your colleagues will provide this year.

Thank you, sir.

[The statement follow:]

Testimony

to

Subcommittee on Science, Technology, and Space

U.S. Senate

May 3, 1990

by

John M. Logsdon

Director, Space Policy Institute

Elliott School of International Affairs

George Washington University

I have spent my professional career tracing the policy history of the civilian space program of the United States, beginning with a book published two decades ago called The Decision to Go to the Moon. I believe that I qualify to make this observation: we are at an unprecedented juncture in the evolution of the U.S. space program. The opportunity to set a productive path to the future has never been greater. Seizing that opportunity requires vision and some risk taking. The opportunity is not likely to last long, or reappear soon. For those who believe that space exploration should be an important element of the U.S. agenda for the 21st century, it would be tragic if the opportunity were missed.

Never before has a U.S. President proposed to Americans that they make and sustain a national commitment to human exploration of the solar system. John F. Kennedy, responding in April 1961 to the problems of the moment, asked his advisers to find him a "space program which promises dramatic results in which we could win." The response was a race to the moon, Project Apollo, not a commitment to exploring the solar system. However grand in conception and significant in the sweep of human exploration, Apollo was at its core a politically motivated use of space capabilities to demonstrate American power and capability to the world and to ourselves.

In the over two decades since that demonstration took place, the central theme of those concerned with the vitality and integrity of the U.S. effort in space has been the need for a coherent long-range purpose against which proposed policies and programs could be evaluated. This need has been seen as particularly great for that portion of the space effort with the highest cost and broadest public interest--human spaceflight. In 1984, for example, Congress mandated a National Commission on Space to chart America's future in space.

Now President Bush has embraced the vision put forth by that Commission, a vision that has motivated space pioneers from Tsiolkovsky and Goddard through Oberth and von Braun, which has been embraced by many of those now working in the U.S. and Soviet space programs, and which continues to capture the aspirations of today's youth. For the first time ever, an American President has put forth exploration of space as something worth doing in its own right. Mr. Bush did not claim economic or military payoffs from a return to the Moon or a voyage to Mars; rather, he justifies such undertakings "because it is humanity's destiny to strive, to seek, to find."

We should be careful with the use of the word destiny. I don't think that the term should be taken as indicating inevitability or predetermination. Rather, destiny should be understood as the result of making specific choices within the overall flow of events and trends. Humanity can help create its destiny through the choices made by individuals and societies at particular times. For space, that time is now.

This, I believe, is the level at which what has become known as the Space Exploration Initiative should be debated, not at the level of specific budgets or particular programs. Mr. Bush's speech last July and the activities that have gone on since under National Space Council and NASA leadership should be viewed as just the starting point in a national discussion of whether this country agrees that 21st century America should be a leader in space exploration. When he proposed Project Apollo, President Kennedy said: "Let it be clear that I am asking the Congress and the country to accept a firm commitment to a new course of action--a course that will last for many years and carry very heavy costs . . . . If we are to go only halfway, or reduce our sights in the face of difficulty, in my judgment it would be better not to go at all. This is a choice that the country must make."

These words apply equally well to today's situation. There needs to be several years of debate within Congress and throughout the country before a commitment to human exploration and expansion is made. But that debate has to start, not be prematurely foreclosed. This is my reading of the intent of the Presidential decisions of March 8 and March 30, on program strategy and international cooperation respectively, and of NASA's plans as outlined this morning by Arnie Aldrich. Congress is not being asked now to make a long-term commitment, but rather to make possible the actions essential to informed choices several years from now. To say that we can't afford to, or shouldn't now begin, the process of shaping a productive long-range purpose for humans in space seems to me to be defaulting on our responsibility for the future.

Yet the reaction to the Space Exploration Initiative from many in Congress and the aerospace industry, and indeed from many within NASA, has been strangely unenthusiastic. Some seem unconvinced that President Bush is serious. They appear unwilling to risk already approved programs and their established positions of power by linking them to the support of the long-range goal of human exploration. There is an ownership issue here. Space policy for over two decades has been the domain of a specialized issue network. Now it is being formulated by the White House and the Space Council. The former custodians of the space arena are having some problems adjusting to this new reality. NASA is being challenged to improve on past performance, and no organization enjoys public pressure and criticism. Admiral Truly does believe the President's words, and is committed to re-forming NASA so that it regains all of its reputation for technical and managerial excellence and integrity. But he and his associates need a signal from leaders in Congress that his efforts in making the necessary changes and setting new directions will receive their support. More fundamentally, the skeptics in the aerospace community need to be convinced that there is adequate political will in both the White House and the Congress to set a broader course for current space activities. Leadership is required at both ends of Pennsylvania Avenue.

We are already engaged in a multibillion-dollar space exploration initiative, in my judgment; what is needed is to acknowledge that reality in order to provide a context for current programs. The space station program, life sciences research, investments in new technology, and imminent space transportation choices would all profit from being recognized as part of humanity's outward movement

During the next several years, our major space investment will be in Space Station Freedom. That program has certainly had its problems, but I believe that it is finally being brought under managerial control. I can understand the reticence of station managers to discuss the implications of the links between station and SEI as they try to ensure that the initial station design is technically sound and financially achievable. However, to me the ultimate payoff, among many, from Freedom will be its contribution to preparing for journeys beyond Earth orbit.

NASA's Life Sciences program is another part of the SEI already underway. In my view, it deserves additional funding and more visibility within NASA than is now the case; the links between many of its scientific objectives and long duration human activity in space are somewhat submerged in its current location within the organization. And it is the kind of relatively low-cost investment now that will enable better quality choices later. That is a characteristic of much of the research on advanced technologies being proposed as part of the exploration initiative.

At some point, the country will have to face up to difficult choices regarding space transportation capability for exploration and other purposes. The impacts of the two-decade ago policy mistake of total dependence on the shuttle for access to space continue to constrain our ambitions in space. There is nothing wrong with the shuttle; what is wrong is the lack of much-needed complementary capabilities and of a clear understanding of the requirements for the next generation of space transportation capability. OTA is about to release its report on _Access to Space_, and I commend it to you for careful scrutiny.

At the start of my testimony, I suggested that there is now an unprecedented opportunity to set a productive path for future U.S. efforts in space. But that opportunity, stemming from--finally--Presidential willingness to lead the country in space, will not last forever. George Bush and his associates could become convinced that the space community won't or can't deliver the kind of program they are calling for. There are certainly many other claimants for the kind of priority that the President has so far assigned to space. But the space community will not seize this opportunity without Congressional as well as Presidential support. That support, and some modest actions to back it up, is what I hope you and your colleagues will provide this year.

I have no doubt humans will return to the moon and journey to Mars in the next century. The issue is whether Americans will be among them, and whether they will be among the principles in the enterprise. In May 1961, John Kennedy said, "we go into space because whatever mankind must undertake, free men must fully share." Human exploration of space is an expression of values central to U.S. identity. We should slowly but certainly begin once again to act on those values.

Senator GORE. Thank you, Dr. Logsdon. Mr. Harrington.

STATEMENT OF JAMES C. HARRINGTON, VICE PRESIDENT, FLIGHT PROGRAMS, KAMAN AEROSPACE CORP., ON BEHALF OF AEROSPACE INDUSTRIES ASSOCIATION

Mr. HARRINGTON. Thank you, Mr. Chairman. I am pleased to be here today to address the issue of returning to the moon, Mars and beyond.

I would like to commend you and the subcommittee Members for commencing the debate on this issue. In November 1989 Vice President Quayle requested the assistance of the Aerospace Industries Association, which I represent today, in developing the administration's space exploration initiative, not human in that case. Specifically, the Vice President sought AIA's help in creating a process that brings together the best of the past with the best thinking, research and application we can possibly devise for the future.

Subsequent guidance from Dr. Albrecht, the executive secretary of the National Space Council, focused the request. AIA was asked to define a process for evaluating and selecting the most promising concepts among a contribution of a broad spectrum of American scientific and technological communities. The process would ensure articulation of all ideas, including those from the traditional establishment.

AIA was further asked to submit views and recommendations and approaches to managing a program of SEI's contemplated size, depth and duration. In December 1989 Don Fuqua, the President of

AIA, accepted the task and agreed to provide an interim report by the end of March.

AIA's Space Committee then set out to form a task force under which I was appointed chairman to produce the report for the Vice President and the National Space Council. As you are aware, the report is issued, and I can enter that report into the record.

AIA and its members recognize that an expedition of this magnitude may not be accomplished within the remainder of the 20th Century; therefore, the task force and its members focused on the benefits and opportunities in providing the Nation with a long-term civilian space agenda through the space exploration initiative.

In a decade of growing global competitiveness, SEI provides a mechanism through which the Nation can benefit from increased technological advancement and industrial productivity. We must, however, find ways of reducing the time and cost of producing major space systems while maintaining reliability and safety. We must incentivize the development of new technologies that provide breakthroughs so necessary to accomplish our space exploration goals while at the same time producing commercially applicable spinoff technologies.

It is with this in mind that AIA and its members recognize the correlation between reaching beyond low earth orbit and leading our Nation to continued economic well being and increasing our quality of life.

Diverting from my testimony, I think the theme we tried to focus SEI on is how does it benefit the quality of American life. If you cannot do that, you do not have a program in today's world.

Along with the opportunity to increase our technological leadership, we also believe there exists a juncture for improving international relationships through joint participation in highly visible, intensely demanding space ventures. With the economies of the European Community uniting by 1992, it is vital that positive dialogue and interaction exist between the U.S. and other European nations as well as within the total international space community. SEI, with its immense possibilities for reaching celestial bodies, provides a forum for nations to join together in the name of space exploration.

Mr. Chairman, our technological leadership and global competitiveness cannot be maintained without a truly realistic recognition that we must inspire the youth of today to prepare for future endeavors by studying science and engineering. The space exploration initiative provides a catalyst to increase interest in science and engineering not only for the Nation as a whole but for those individuals who will carry on the exploration of space.

AIA believes that the early planning phase of SEI offers an opportunity to make this program an integral part of America's overall strategy for the future. To take advantage of this opportunity the U.S. must put in place a strategy that will sustain space exploration over multiple administrations, Congresses and political events.

The strategy implementation must be a carefully considered set of actions that result in the development of the broadest possible constituency supporting the space exploration initiative.

This theory rationale is not too unlike the great debates that preceeded the go-ahead for this nation's Interstate Highway system.

Although not directly to point, many of the same questions and problems such as multiple government functions, within the implementation process had to be factored.

Considerations must be given during the initial debate on SEI to the fact that many Americans recognize the technological and economic benefits that result from space exploration. The American public has supported exploration in space for the past 30 years. Its role in expanding our world economy in a generation of quality job opportunities through new products and service is the success story of the space age.

It should also be noted that to establish the path for a program such as SEI, both the executive and legislative branches of government must agree on a series of multi-agency objectives and milestones to be achieved.

Further and in the interest of stability, both branches of the government must set forth a common purpose or set of objectives and clearly define long term funding sources.

Mr. Chairman, in response to the Vice President's request, our task force review led to an innovative process and methodology for systemically addressing the issue of "how" and "in what manner" we should venture back to the Moon, Mars and beyond. The AIA task force selected criteria for an effective and efficient process and proceeded to recommend that an independent facilitator be appointed under the direction of a NASA-appointed and National Space Council-approved leader.

This independent organization would be operated in a manner quite similar to the Fletcher study in coordination with the Institute for Defense Analysis (IDA) as the facilitator. Four teams would be formed; (1) strategy/objectives team; (2) rule makers team; (3) evaluation team; and (4) solution team. The objective of this organization archetype is to cast the widest net possible to gain access to all proposals, architecture and technology to solve the problem of getting to the Moon and Mars. Experts from government, industry and academia will all be participants in the organization of the four teams. Final recommended architectural solutions and technologies will be submitted to the National Space Council for policy decision making, and NASA for recommended technology pursuit.

In summary, AIA and its members view the initiation of the President's space exploration initiative as a major step toward retaining and enhancing American technical and industrial competitiveness. SEI captures the American spirit of conquest of the unknown and continues our tradition of exploring new frontiers.

AIA believes the recommended process brought forth from the SEI team provides a mechanism by which the input resulting from a broad request of diverse segments of the Nation's technical community can be given unbiased analysis and evaluation against overall objectives and policies of the country.

The process provides for a means of looking at the real alternatives and measuring them not only by their technical content but also incorporating social, educational, environmental, political and international factors.

Finally, it provides for an orderly transition to program implementation.

Thank you, Mr. Chairman.

Senator Gore. Thank you very much. Let me run through some questions briefly.

Do we currently know enough about the effects of long term space flight to be certain that humans will be able to make this long trip and return without significant adverse effects on their health, General Stafford?

General Stafford. Well, Mr. Chairman, the Soviet Union with their MIR program has had three cosmonauts that have been in space, two of them for over a year, one for nearly a year. They had minor readaptation problems when they came back to the Earth, but within two to three weeks they were perfectly adaptable.

As far as going out to the Moon, that is a short duration out there, Mr. Chairman. It is three to four days out and back.

As far as Mars, every 26 months when it comes in conjunction it is about one year out and one year back using chemical propulsion.

So there are a lot of questions still to be answered, Mr. Chairman. That was outlined in our review of the NASA study, and there are ongoing efforts for that.

Senator Gore. All right. More research is needed, in other words?

General Stafford. Yes, sir. More research is needed.

Senator Gore. We do know enough to suppose that it is clearly within the boundaries of what is feasible in terms of the impact on human health?

General Stafford. That is correct, sir.

Senator Gore. Do we know how to create a self-contained life support system that will sustain human beings for more than a year without resupply?

General Stafford. We reviewed that, again, in the National Research Council. One of the high leverages you get is in recycling the water, and that is certainly feasible. You do not grow your own food, but you recycle the water, and you have certain types of recycling of oxygen and CO_2, but the high payoff, Mr. Chairman, is recycling water. So there are various systems and subsystems that are feasible, and we have made certain demonstrations of them on the ground and experiments in flight as to recycling. So we could do that. Still, you have to carry your own food.

Senator Gore. Do we know how to make the rocket engines we will need to get to Mars? How likely is it that nuclear propulsion will end up being the method of choice?

Mr. Harrington. I think we are going to leave the technical questions to the General.

General Stafford. I will answer that, too, sir, since we reviewed it in great detail. In the past NASA had a program called NERVA that had a nuclear thermal rocket in which you have liquid hydrogen in a tank pressurized with a turbo pump and running through a reactor to expand and accelerate it out through the nozzle. That was successfully ground test fired in the late 1960s and early 1970s. The program was terminated when there was determined to be no further use for it in that time frame.

Today it looks like technology has advanced, so in the year, say, 2010 or 2020 a nuclear thermal rocket would certainly be feasible, assuming that you added all the safety criteria and had political acceptance. It could drastically reduce the time to Mars, say, from a year down to three or four months.

Senator GORE. Do we have the lightweight yet durable materials needed for a manned Mars vehicle?

General STAFFORD. I would refer again to our study. The main effort on the material, sir, is we have a lot of composites in development, and we anticipate with the use of aerobraking, which is a new technology to be demonstrated, along with the type of materials we forecast should be adequate to do it.

In fact, aerobraking will be an experiment on the shuttle, I think, in 1992 as a first experiment.

Senator GORE. Do we know enough about the radiation levels and micro meteorite densities of interplanetary space to be sure that astronauts would be safe on a journey of this kind?

General STAFFORD. We have a lot of data from our unmanned planetary probes, the Voyagers and Explorers that have gone out, so that the mathematical model of interplanetary space is fairly well known.

What has become a problem lately in earth orbit is a lot of the debris from all of the nations that are putting up satellites into earth orbit. As far as the interplanetary, we have a fairly decent model of that, Mr. Chairman.

Senator GORE. Now I raised the question earlier with the first witness about U.S.-Soviet cooperation and perhaps broader cooperation as well with ESA and other spacefaring nations. The National Research Council Report evaluated the administration option, the go-it-alone approach, and the position advocated by Carl Sagan and Raul Sadayev and others, a joint manned mission.

The NRC favored a third intermediate option calling for coordinated but not cooperative missions where each nation would mount its own Mars program which would be designed to complement and not duplicate what the other nations are doing.

Which of these options do you think is best, any of the three of you?

Mr. HARRINGTON. I will take a shot at that, Mr. Chairman. I think there are a number of reasons. The AIA report specifically focuses on international cooperation and partnership. The word "partnership" is meant to be a measure of dependence, not a program where they just provide pieces and we assemble and run it; a real partnership.

I think we all believe that America cannot go it alone financially with a program of this size. I sat here and listened to the discussion earlier about budgets and concerns of deficits, and I think in my mind that is a fact. We need to combine our resources.

More importantly, if we want to focus on the quality of American life and on John's comment about now is the opportunity, there is a peace opportunity today, and no one can tell whether that peace opportunity will be around two years from now. A mechanism for solidifying that is to get the Europeans, the Japanese, the Russians, the Canadians and others into a long term space initiative financially and collectively.

Senator **Gore**. So you are for that option?

Mr. **Harrington**. I am for a global program.

Senator **Gore**. That is the AIA position?

Mr. **Harrington**. Yes, sir.

Senator **Gore**. Well, it sure makes sense to me.

Dr. Logsdon?

Dr. **Logsdon**. We are currently engaged in the largest experiment in international technological cooperation ever undertaken—the space station program, and I think the results to date show that at the level of principle it is an inarguably good thing to do and at the level of practice it is hard.

I think we have to learn from the station cooperative experience as we look forward to international engagement in the Exploration Initiative.

Senator **Gore**. One of the reasons it is hard is that we get started on a program and then we cannibalize it to make room for all of these other new programs when new money is not provided. Then our international partners get extremely unhappy when the redesigns leave them out in the cold sometimes.

That is part of the problem, is it not?

Dr. **Logsdon**. Indeed. Our partners are having some problems of their own getting their own technical act together. Both technically and managerially, doing long-term complex projects in intimate cooperation is hard. To say it should be done is unarguable. To say that it can be done is going to be an art of really managerial and leadership skill.

With regard to the Soviet Union, I think General Stafford should talk about the experience of doing a coordinated mission, since he did one. We have now had 15 years of not working closely together, and I think we have to reestablish, and we have to learn each other's patterns in a very new era. So I am rather cautious in making a commitment to the character of cooperation, but certainly we need to all be working together.

Senator **Gore**. General Stafford, you bring a kind of unique perspective to this question. What do you think about it?

General **Stafford**. Well, sir, I feel that the exploration, particularly back to the moon but even more so to Mars, should be an international cooperation. I know on behalf of the Soviet Union it was a very short period of time. It was very intense, and it was very successful. Working with more than one country is, I know, difficult. I had a heck of a time with my Oklahoma accent learning the Russian language, sir, but it worked out very well, and I am all in favor of it.

Senator **Gore**. That is great. I think we are really in a new era now. The Cold War is over; the Berlin Wall is down; Communism is collapsing. People of the world, while patriots in their respective nations, now feel themselves to be part of an emerging global civilization, one I hope and pray will be led by the United States of America.

In regard to massive new ventures which involve humankind as a whole, it now makes sense to work cooperatively where possible, whether it is the human genome project or the effort to understand the global environment or the effort to explore the solar system. It just makes sense to begin thinking in these terms. I think your testimony here is very instructive on that.

Potential showstoppers: We have put a man on the moon several times. We know that can be done. Putting a man on Mars would be a much bigger challenge. Are there potential showstoppers that would force us to abandon such plans? Do you see any on the horizon other than budgetary?

General STAFFORD. In the review we had, sir, the only one that we said could be a showstopper would be basically the human endurance over long periods of time. Engineeringwise, technically we know how to do it.

Senator GORE. Do you all agree on that?

Dr. LOGSDON. Let me just add that you would put it again in terms of budgets, and that is in practice what we are talking about. The question is, however, is there will to do this? The showstopper is a failure of will.

Senator GORE. Well, a failure of will can be manifested in a variety of different ways. A failure of will can be seen in the absence of leadership on the question of how we are going to pay for this. Again, you all do not need to get into that. If you have any thoughts to offer on that, I would welcome them. I will not press it.

Dr. LOGSDON. I do.

Senator GORE. I would like to hear them, then.

Dr. LOGSDON. As a university professor, I am supposed to have thoughts on everything anyway.

I think one has to ask when is this money going to be spent. What is a reasonable funding profile for the mission we ultimately choose or the undertaking that we ultimately choose to look at? If we are going to Mars in the 2015 to 2020 period, the funding for Mars is going to be sometime after the turn of the century, not in this decade.

Senator GORE. Wait a minute. It is $200 million this year.

Dr. LOGSDON. The multi-billion dollar funding——

Senator GORE. I will not quote Everett Dirksen for the billionth time, but when you get into the hard choices made by NASA each year now, $188 million this year and ramped up, true, it is a good point you make. The tens of billions of annual expenditures are some time off, but the steadily growing bow wave has implications almost immediately. There are things like the high performance computing initiative which can suffer this year because of the funding for this.

So your point is well put. And I think that is a valuable addition to the record here and the discussion we have had on it.

The underlying point is still valid, I think, that without identifying the source of funding we are really kind of asking for trouble. Look at the space station. Now the President has gotten involved and is showing some leadership on the space station, but we are really asking for trouble, I think, unless we can get from the administration some realism about funding.

Do you all want to offer anything to this?

Mr. HARRINGTON. Could I offer a few comments, Mr. Chairman?

Senator GORE. Sure.

Mr. HARRINGTON. Listening to the discussion this morning, it comes to me that the question is not whether we do this but when we do this. America is going to go to Mars and probably back to the Moon.

Why go back to the Moon? It is a good question. I think there are some good answers. We are going to do it. The question is when. I think that is the real focus. I do not believe we as a community have enough information to make an intelligent decision today. That is why we offer a process that might take two years to come up with. What are the major options, and what do they cost, and how do you fund that?

I think the point is at this juncture we are not in a technical process. We are in a political process.

Senator GORE. It is a political process. I agree. We are coming off a nine-year period in which the Reagan-Bush Administration engaged in a leveraged buyout of the U.S. economy. We have this massive savings and loan scandal getting worse by the minute. I think it is costing us more than $30 million every 24 hours now, the highest monthly budget in the history of the United States last month.

You are right. It is a question of political decision, a question of will, and a question of when we can resolve these matters sufficiently to undertake an historic initiative of this kind.

Did you want to comment?

General STAFFORD. With respect to costing, at the National Research Council, we are asked to give estimates on it. Again, all we could give is a certain measure of merit based on past programs and technologies, Mr. Chairman.

Today the NASA budget varies between two-tenths and approximately three-tenths of 1 percent of the GNP. We said that, again as a rough measure of merit, over a period of time it would probably have to go to about double that number. However, we have not reached the peak of GNP that Apollo had. Apollo I think was eight-tenths of 1 percent at the peak year of Apollo, and we have not reached that.

Senator GORE. All right. Some other Members of the subcommittee may as have questions, to which I hope you will be responsive.

I think this is a good stopping point for the open session here. I really do appreciate the three of you taking the time to come and help us think this problem through. We have some tough decisions to grapple with, and I hope the administration does get the message which many of us are trying to send on the budgetary realism. I hope that we will find a way to answer those questions. We are farther down the road, thanks to your testimony, and we certainly do appreciate your presence here.

Thank you.

[Whereupon, at 11:50 a.m. the hearing was adjourned.]

SPACE SCIENCE AND APPLICATIONS

THURSDAY, MAY 10, 1990

U.S. Senate,
Committee on Commerce, Science, and Transportation,
Subcommittee on Science, Technology, and Space,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:35 p.m., in room SR-385, Russell Senate Office Building, Hon. Albert Gore, Jr., (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORE

Senator Gore. The hearing will come to order.

Today we will continue our hearings on the NASA budget request for fiscal year 1991 focusing this time on the space science and applications programs.

To help us review these critical programs we are fortunate to have Dr. Len Fisk, NASA's Associate Administrator, who will outline the President's budget request for space science and applications as well as specific research programs in astrophysics, earth and life sciences, planetary exploration, materials processing and communications technologies. A panel of distinguished witnesses will follow enabling us to better evaluate NASA's effectiveness in meeting its stated objective of developing a coordinated and logically phased space science research program.

As chairman of this subcommittee, I am especially pleased with the funding increased proposed for fiscal year 1991, which is 20 percent above current levels. Unlike last year, the President's budget assumes no major program or mission terminations. However, given the realities of Gramm- Rudman and our current fiscal situation, some will undoubtedly question of wisdom of funding requested increases for fiscal year 1991, and so it is imperative that we build a strong record today on the importance of these programs.

NASA's space science research is a critical part of our effort to better understand the earth, the universe and how humankind can better live on this planet. And, secondly, it will help attract the youth of this country into the fields of science and engineering.

This is an issue of great interest and long-term concern to me. Earlier this week I chaired a subcommittee hearing on the projected shortages of scientists and engineerings in the United States. Very simply, the competitive position of our country in the world marketplace will depend upon our ability to compete at high technology markets. Without enough well trained scientists, engineers and technicians, the U.S. will be at a competitive disadvantage compared to other nations. It is, therefore, incumbent upon us in this body to do all we can to ensure that we meet that challenge.

A perfect example of how NASA's space science research programs can capture the interest of the American people and, in fact, the world is the Hubble Space Telescope, the first of the four great observatories launched last month. Years in development, thousands of individuals have worked to make it a reality, and I congratulate NASA through you, Dr. Fisk, for this remarkable achievement.

We had hoped to have some of those first images for today's hearing, but, of course, everyone understands that the temporary problems have to be worked out carefully and skillfully. With all of the technicians at NASA who are even now busily engaged in that process, it is such an exciting development, we are all really celebrating with you. Millions of young people are eagerly awaiting those first images and pictures that will capture the imagination of young and old throughout the world.

It is possible those images of the universe will just do more to convince students that science, math and engineering can be fun and exciting than any book or lecture or View Graph, however well intentioned.

It also should come as no surprise to this audience that the subcommittee and I have a great deal of interest in how space science data is managed and utilized. Earlier this year the General Accounting Office partially criticized NASA for its management of data transmitted from earlier space science satellites. While improvements are underway by NASA to better manage space science data, it is essential that we have in place an information system capable of processing, storing and distributing data from both existing and future space science missions. This will become even more important as we begin to receive the massive and unprecedented volumes of data from the Earth Observing System.

We will also cover a number of other important programs at today's hearing. The Hubble has been launched, but other space science missions are now being prepared, most notably the Gamma Ray Observatory and the Ulysses spacecraft to the sun, which are both scheduled for launch later this year.

Activity and materials processing and life sciences, which is seeking cures to life-threatening diseases and developing new wonder drugs must be examined. Finally, while we have covered EOS and the Mission To Planet Earth in some detail at an earlier hearing, we cannot ignore its place among other space science programs because, in my view, EOS is one of the most important new starts to ever come before this subcommittee.

So without further ado, let me welcome all of our witnesses and tell all of you how much I look forward to your testimony.

At this point, let me introduce our first witness, Dr. Lennard Fisk, Associate Administration with the Office of Space Science and Applications at NASA.

Dr. Fisk, you are a frequent visitor to our subcommittee, always welcomed and respected. If you could start by introducing your colleagues at the witness table, that would be helpful.

STATEMENT OF DR. LENNARD A. FISK, ASSOCIATE ADMINISTRATOR, OFFICE OF SPACE SCIENCE AND APPLICATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY KATHRYN SCHMOLL, ASSISTANT ASSOCIATE ADMINISTRATOR IN CHARGE OF RESOURCES AND ADMINISTRATION; AND AL DIAZ, DEPUTY TO THE ASSOCIATE ADMINISTRATOR

Dr. Fisk. Thank you very much, Senator. It is a pleasure to be here. On my right is Al Diaz, my deputy, and on my left here is Kathryn Schmoll, who is the Assistant Associate Administrator in Charge of Resources and Administration.

If I may, I have a statement for the record, and if I could just submit that and perhaps make a few informal comments to start with.

Senator Gore. That would be great, and without objection your prepared statement and the prepared statements of our later witnesses will all be included in full in the record. Please proceed.

Dr. Fisk. Thank you. As you noted, we have had a hearing on mission to planet Earth, and this is, of course, our important and very essential new start this year, but I thought since we had already had a hearing, I would concentrate my opening remarks on other aspects of the space science program.

I was thinking the other day as I was thinking about what to say here in the beginning, a year ago when we were here, we had not launched a major space science mission in more than five years, and we had not launched a planetary mission is more than a decade.

A lot has happened in the year since I testified here last on the overall space science program, and the program today is substantially different. Magellan went off, I think, shortly after the testimony in May of 1989. It will get to venus in August of this year and begin its mapping cycle of the planet. We had the Voyager encounter in August, which was a magnificent event, not only from the science that it did, but for the public interest and involvement in the program. Galileo went off in October and got to Venus actually ahead of Magellan in February, and it is on its way back to the Earth. In December we will do a fly-by and then another fly-by of the Earth in December of 1992, and then head out to do its exploration of Jupiter.

Cosmic Background Explorer went up in November and is literally presenting some very interesting challenges about our understanding of the origin of the universe. The radiation that is seen from the primordial big bang is remarkably smooth, and it sort of challenges our understanding of how the universe which seems to have started out very homogeneous ended up as in-homogeneous as it is today.

We even launched something called PEGSAT, which is a small mission. We flew on the first flight of the Pegasus rocket which was dropped from NASA B-52 and did some chemical releases in the ionosphere.

And, of course, you mentioned Hubble. Hubble is doing well. We had set aside approximately a three-month period in order to test out the spacecraft. This is called orbital verification one, to be followed by a second three-month period or orbital verification two, to do the instrument calibration and get ready for what will hopefully be routine operations. And we are working our way through orbital verification one.

It is a complicated spacecraft, and it is smarter than we are. Occasionally we send it a command that it does not like, and it goes into a safe mode, which is what it is designed to do. We had a few of those in the beginning. We have not had one in more than a week now, and I am very pleased by the performance of the spacecraft. We have seen nothing on the spacecraft that makes us think that this will not be the exciting mission that we expect it to be.

We have had to do some adjustments in the software because things behave differently in weightlessness than you can ever model successfully on the ground, and when you have a telescope and its science instrument as delicate as this, even small shifts or changes in weightlessness have to be adjusted out of the telescope to get the full performance out of it. And so the telescope is doing well, and we will see a first picture in a few days or a week and shortly thereafter, we will begin to see exciting pictures come down. And, of course, eventually routine science. So this one is going well.

ASHTRO is on the pad, and it is going to complement Hubble nicely looking at the ultraviolet radiation and X-rays and there is a very interesting science lesson from space to be conducted from ASHTRO. We are going to actually conduct using the crew with a lesson on the spectrum, the electromagnetic spectrum which is aimed at middle school children, and they are actually going to participate in the lesson being hooked to the communication with the astronauts from both Goddard and Marshall Spaceflight Centers, and it is all part of an effort to use the visibility of the NASA space science program to excite young people to think about careers in science and engineering.

We have ROSAT, an X-ray satellite, with the Germans to go off in early May. We have a chemical release radiation environment satellite joint with the DOD to go off in June. Space Life Science I goes in August. Ulysses goes in October. The gamma ray observatory goes in November, and the International Microgravity Lab I goes in December. That is 13 missions in 18 months. That is more missions for space science than we flew in the entire decade of the 1980s.

We have a strategic plan that we developed three years ago, and we have this maddening habit of following it each year, and it is intended to preserve this level of activity well into the next century. We try to balance major, moderate and small missions, get ready for space station and preserve the research base that is the foundation of the program.

This balance between large and small missions is important to us. Last year we started three small explorer missions. These are scout class spacecraft and two Delta class explorer missions for expendable launch vehicles. We are also concerned about the research and analysis base that is the foundation of the program, but it has seen some growth in real year dollars, but real growth in dollars above inflation, but it is still stretched and it did suffer some damage in the 1990 time frame due to Gramm-Rudman and drug taxes when they were applied.

As you noted, the budget for fiscal 1991 is a very good budget. In my judgment, it is healthy. It does not have the kind of holes in it that previous budgets have had. There is funding for the advanced communication technology satellite. There is funding for the preparation of gravity probe B, and all in all, I think it is very well balanced. It will sustain a healthy and active space science program for the United States for years to come, and I would be very pleased to answer any questions that you have about it.

[The statement and questions and answers follow:]

Statement of

Dr. Lennard A. Fisk
Associate Administrator for
Space Science and Applications

National Aeronautics and Space Administration

Mr. Chairman and Members of the Subcommittee:

I am very pleased to have the opportunity to appear before the Committee.

When I appeared before you for last year's authorization hearing, the United States had not launched a major space science mission in more than five years, or a mission to the planets in more than a decade. Today, Magellan is enroute to Venus and Galileo to Jupiter. The Hubble Space Telescope will open a new window on the universe, and is undergoing its science verification and testing phase in preparation for its fully operational phase as a research facility in space. Seven additional Space Science missions are scheduled for this year alone. This launch rate will continue year after year into the next century. We have crossed over the horizon into a new era in Space Science, into a second golden age. We will, in the next few years, expand our knowledge of the universe in which we live more rapidly than at any time in human history.

As we enjoy the excitement of this second golden age of space science, however, we need to be concerned about the future of the human species. We live in a unique time, where human actions may be affecting the environment on a global scale. The impact of these human activities is uncertain. It is time to reduce the uncertainty by developing sufficient knowledge of how the Earth works, and what we are doing to it, so that we can be wise stewards of our future.

The President has proposed in the FY 1991 budget an aggressive, multi-agency research program to reduce the scientific uncertainties associated with global change. NASA is central to this activity. We are to apply our expertise in remote sensing to use the global perspective that is available from space to understand how the Earth works as an integrated system. We call our program Mission to Planet Earth. It consists of (i) some nineteen near-term flight missions, including the new Earth Probes program, that will expand our knowledge of aspects of global change; (ii) an integrated and open data system that will be available by 1994 to draw maximum information from existing and upcoming missions; (iii) an expanded scientific research program; and, (iv) a new start in the FY 1991 budget for the Earth Observing System, which will provide comprehensive, long-term observations of the whole Earth and its component parts, sufficient to serve as the basis for predictive models of the future of the planet.

Mission to Planet Earth is unlike any other NASA Space Science Program. It is not intended to increase incrementally our knowledge of the Earth. Rather, it is intended to increase with all due haste our knowledge of all aspects of the Earth system to where we have sufficient understanding to make sound policy decisions. This will require aggressive and sustained funding.

However, consider the alternative. It is clear that global changes can have significant economic and sociological impact on our nation. Indeed, the economic impact of a decision to drastically reduce fossil fuel consumption could be measured in hundreds of billion dollars per year. Thus, we must make the investment today that will reduce the scientific uncertainties associated with global change issues, so that our actions can protect both the future of our environment without unduly jeopardizing our economy and way of life.

There is a bright side, as well, to the prospects of the future of the species. The time may come when we will work on other planets, extending our presence throughout the solar system. And we have the good fortune of being the generation that will begin the journey.

The President has called upon us through the Space Exploration Initiative to return to the moon, and then proceed to Mars. Science is an integral part of this activity, and in the FY 1991 budget we provide support (i) for life science research which is essential to any human activity in space, (ii) to continue the robotic exploration of the moon and Mars, and (iii) to undertake planning for the unique opportunities for science that the moon offers.

The FY 1991 budget request for NASA is of historical significance. It provides for a renaissance in space science; we will marvel at the discoveries that will unfold before us in the coming years. But more important, it is a budget request that future generations will look back upon and be grateful for our wisdom. It begins the lengthy process of developing a sufficient understanding of the Earth so that ours and future generations can know the consequences of their actions. It begins the inevitable journey of this civilization into the solar system.

Permit me now to describe in more detail some of our recent accomplishments and our plans for FY 1990.

1989 PROGRESS AND ACCOMPLISHMENTS

In May, the Space Shuttle deployed the Magellan spacecraft, which will arrive this August at Venus, where it will spend several years mapping the planet's surface. In August, 4.4 billion miles and 12 years after launch, the Voyager 2 spacecraft arrived at its final destination on its "Grand Tour" of the outer planets -- Neptune, and literally excited the world with its discoveries. In October, Galileo began its circuitous journey to Jupiter, where it will drop a probe into the Jovian atmosphere and perform an extended tour of its satellites. Finally, in November, we launched the Cosmic Background Explorer (COBE) to measure the radiation remaining from the "Big Bang." Exciting early data from this mission has already challenged our present understanding of the early universe.

1990 PLANS AND OBJECTIVES

NASA's launch manifest calls for eight major Space Science launches in 1990; six on the Shuttle and two aboard expendable launch vehicles. In addition to the ambitious number of space science launches planned this year, many of our operational spacecraft will achieve significant scientific milestones in the coming months. Voyager 1 has completed its look back at the planets, and the 64 images it collected will be pieced into a photo mosaic of our solar system which will be available later this summer. Galileo completed its Venus flyby in February, testing its scientific instruments and acquiring the momentum necessary to carry it by the Earth in December, and eventually on its way for a 1995 rendezvous with Jupiter. COBE completes its first sky survey in June. Magellan arrives at Venus on August 10, and begins mapping operations.

OSSA STRATEGIC PLAN

To attain and continue this unparalleled level of activity, we have diligently practiced strategic planning for our Space Science and Applications (OSSA) program. Now in its third year, the OSSA strategic plan continues to act as a guide with which to manage our ongoing programs and to plan for the future. The strategic plan continues to balance the need for major, moderate, and small missions. The plan charts our course as major users of Space Station Freedom. It affirms the importance of a strong research base. Perhaps, most importantly, the plan provides a clear process for making near-term decisions to allocate resources and plan for the future.

The strategic plan expands this year to be responsive to two major Presidential initiatives, while preserving the integrity of OSSA's core programs.

The fiscal year 1991 budget follows the five basic themes outlined in the OSSA core strategic plan, and also provides strong support for the U. S. Global Change Research Program and the Space Exploration Initiative.

ON-GOING PROGRAM

First, we have provided for the completion of our on-going programs. On April 25, the Shuttle deployed the Hubble Space Telescope, a cooperative program with the European Space Agency. The first of the four Great Observatories, Hubble will probe the universe with exceptional precision and clarity, allowing us to see farther than ever before, revolutionizing the study of astronomy. Next week, we resume our series of scientific research laboratory flights on the Shuttle with the launch of the Spacelab mission, Astro-1, carrying four telescopes which will detect ultra-violet and X-ray radiation from some of the most chaotic and fascinating objects in the universe. Astro-1 will also feature the shuttle astronauts conducting a live "space classroom" lesson on the astronomical features being observed by the telescopes. Also in May, the joint U.S. and Federal Republic of Germany Roentgen Satellite (ROSAT) will launch aboard a Delta

II rocket to study X-rays from cosmic sources. In June, the Combined Release and Radiation Effects Satellite (CRRES) will be sent aloft on its Atlas Centaur rocket to map the Earth's radiation belts during the peak solar activity cycle known as solar maximum. In August, the nine-day SLS-1 mission will fly as the first in an ongoing series of dedicated Life Sciences Spacelab missions. In October, it's back to the planets again with the Shuttle launch of the joint NASA/European Space Agency Ulysses mission, first to Jupiter and then over the poles of the Sun. November ushers out the second of the four Great Observatories, when we deploy the Gamma Ray Observatory from the Shuttle to investigate the forces of neutron stars and black holes. Finally, we will close out the calendar year with the third Spacelab mission of 1990, the International Microgravity Laboratory, focusing on both materials and life sciences research.

Our ongoing program also continues the development of important projects like the Upper Atmosphere Research Satellite (UARS), scheduled for launch in 1991; the joint NASA/French Space Agency Ocean Topography Experiment (TOPEX/POSEIDON) and the Mars Observer, both scheduled for launch in 1992; the Advanced X-Ray Astrophysics Facility (AXAF), with a 1997 launch date; and the Comet Rendezvous Asteroid Flyby (CRAF) and Cassini missions with our partners, Germany and the European Space Agency, planned for launch in 1995 and 1996 respectively.

LEADERSHIP INITIATIVE

The strategic plan also provides for programs designed to maintain U.S. leadership in space science and applications. The Earth Observing System (EOS), the centerpiece of the Mission to Planet Earth and an essential component of the President's U. S. Global Change Research Program, will provide U.S. leadership in the search to understand our environment.

It is important to realize that EOS is a research program which is designed to yield the maximum information about the Earth, and any impacts due to human activities, in the shortest possible time. It provides for a data and information system that will enhance the return for existing missions and missions that will fly in the next few years. It provides for an immediate and substantial growth in support for scientific research. EOS provides the comprehensive long-term observations necessary to understand how the Earth responds to human interactions. Indeed, the bulk of the funding for EOS will support the acquisition and analysis of data, and its scientific interpretation. Only 40% of the total program funding is for space hardware.

During the next several years, our knowledge of the Earth will increase substantially. NASA will conduct 19 Earth science missions, which will study various aspects of how the Earth works. The Upper Atmospheric Research Satellite will make definitive measurements of the chemistry and dynamics of the upper atmosphere, and thus of ozone depletion. TOPEX/POSEIDON will reveal more about the circulation of the world's oceans than all the ships in history. The NASA Scatterometer will study wind stress on the oceans. The ATLAS Spacelab missions will study the atmosphere, and the Shuttle Radar Lab, the topology of the land. There will be numerous Earth Probes: small missions in Earth science to pursue focused problems. Also, our international partners, the Japanese, Europeans and Canadians, will launch seven missions, some of which will carry U.S. experiments, and many of which we will help track in return for access to their data. And NOAA will continue to operate meteorological satellites.

To make optimum use of the data from these upcoming missions, we need to improve the computational capabilities in Earth science, and the access of researchers to this data through networks and archiving facilities. Included in the funding for EOS is substantial support to develop the EOS Data and Information System (EOSDIS), essential elements of which will be brought online in the early 1990's, well in advance of the launch of the EOS platforms. EOSDIS will allow scientists to derive maximum information from existing and upcoming missions, and, in turn, to use this mission data to test and perfect EOSDIS in advance of the larger data flows from the EOS platforms. Moreover, the open architecture of EOSDIS will herald a new era of data management and exchange, among U.S. researchers and with those from other nations.

Data alone, of course, does not yield understanding. That will require scientists interpreting the data, developing concepts for the processes which control the Earth, and building predictive models of its future. EOS includes funding to effectively double the research community that will dedicate itself to understanding global change, and the program will support graduate fellowships to insure continuity of this research base into the future. The funding for scientific research is built in from the inception of the EOS program.

We need to recognize, however, that the Earth may be the most complicated planet in the solar system, with its interactions among the atmosphere, the oceans, and the biota, and that we are remarkably ignorant of how it works. Consider, for example, aspects of greenhouse warming. Carbon dioxide from industrial activities is growing in the atmosphere and has the potential of increasing the temperature through greenhouse warming. However, the amount of carbon dioxide in the atmosphere depends on the amount absorbed by the Earth's biota. The response of the atmosphere to increased greenhouse warming may depend on whether there is a change in the cloud cover of the Earth, and at what altitude the clouds form. The response of the climate, in particular regional effects, will depend on changes in the global circulation of heat through the oceans. Indeed, the response of the Earth to human interactions will depend on the coupling and interactions which occur among the various components of the Earth. These couplings provide feedback mechanisms that could either enhance or mitigate the effects of global change. The essential challenge to us, then, is to understand which feedback mechanisms are dominant, and how the Earth will respond.

The Earth science missions that will fly in the next few years will advance our understanding of the Earth and its systems. They will, in essence, tell us where we are. They will not tell us what to expect in the future for our Earth. They will not yield definitive answers to how the coupling and feedback systems of the Earth work, and thus to how the Earth will respond to global change. In some cases the instruments that will fly have inadequate resolution and sensitivity. More important, they will not provide comprehensive observations of the components of the Earth at the same time. To understand how the oceans, atmosphere and biosphere interact and are coupled, it is necessary to observe the changes in these components, and the resulting responses in other components, at the same time.

The EOS platforms are designed to provide the necessary observations to understand the Earth as an integrated system. The first platform, which will launch in FY 1998, is devoted to measurements of the surface of the Earth, and to the conditions of the lower atmosphere. The second platform, which will fly two and a half years later, is devoted to measurements of the chemistry of the upper atmosphere, the circulations of the oceans, and the behavior of the solid Earth. In addition, our international partners, the European Space Agency (ESA) and Japan are planning to build platforms which include accommodations for U.S. scientific instruments. All platforms are placed in polar Sun-synchronous orbit, to offer complete coverage of the Earth. Simultaneity is the key to successful observations by the EOS platforms. The size of the platforms has been dictated by the science results required to measurably advance our understanding and predictive abilities. We have sought the constant involvement and advice from the Earth science community on the design of EOS, the choice of instruments, and the approach toward scientific research and data processing. In particular, the science community has consistently noted that a long-term, comprehensive set of simultaneous observations is the key to the success of the EOS program. Our fundamental concerns are assuring that the instruments are available in a timely fashion and ensuring that our program meets the scientific priorities and requirements laid out by the U.S. Global Change Research Program.

In line with these requirements the platforms are sized to accommodate those instruments which need to observe the Earth simultaneously, through the same column of air. All instruments that observe the surface of the Earth require substantial atmospheric corrections; knowledge of aerosol content, temperature, water vapor, etc. Thus, it is important to fly all the surface imagers and the instruments which determine atmospheric conditions on the same platform. This requires a total of eleven instruments, approximately 3000 kg of payload, to be flown together. This number of instruments is approximately equal to the number accommodated on the Upper Atmosphere Research Satellite (UARS); however, given the complexity of the EOS instruments, the total payload weight is 30% greater than that of UARS.

We need to track the global environment for some years to ensure that we understand the changes, and the processes responsible for them. EOS is designed to yield fifteen years of continuous data. Since the EOS platforms are in polar orbit, where there is no servicing from the Shuttle, and a reasonable design life for a spacecraft is five years, each EOS platform and instrument will be replaced on orbit twice by an identical platform, at five year intervals.

Processing the flow of EOS observations is critical to mission success. EOSDIS will handle about 10 terabytes of data every day -- about the equivalent of ten warehouses of magnetic tapes. And it will do so quickly -- we plan to process some data within 48 hours of receipt, to allow scientists to get their hands on it as soon as possible. To do this, EOSDIS will use a network of active archive sites and processing centers, and software to allow researchers to browse the files and order only what they want.

The EOS program will be managed by the Goddard Space Flight Center (GSFC). The FY 1991 budget includes funding to augment the workforce at GSFC in direct support of the EOS program and begins funding necessary to undertake construction of an EOSDIS facility. Both of these elements are integral to the total EOS program.

The cost of EOS through the year 2000, including the instruments, the platforms, the data system, and the support for science, is approximately $17 billion, in real year dollars (inflation included). This cost is, of course, large compared to the cost of any previous space science project. However, the cost is very small compared to the value of the information EOS will provide to help chart the course this nation and the world should follow to insure both a healthy environment and a healthy economy.

SMALL MISSIONS

Third, the OSSA strategic plan provides for new flight opportunities in the near term for small missions. This year's small missions initiative responds to the critical and immediate need to address specific and highly focused problems in the Earth sciences. Earth Probes occupy a special niche as critical elements of the Mission to Planet Earth initiative, and are highly symbiotic in their relationship to both EOS and other NASA Earth sciences satellites. A series of Total Ozone Mapping Spectrometer (TOMS) instruments, with potential flights in 1991, 1993 and 1995, will measure atmospheric ozone concentrations and contribute to our current ozone models. The NASA Scatterometer, to be launched in 1995 aboard the Japanese ADEOS spacecraft, will study wind stress on the oceans and provide data needed in understanding the role of oceans in controlling climate. A number of other Earth Probes missions are proposed, e.g. the Tropical Rainfall Measuring Mission (TRMM) and an Ocean Productivity Experiment (formerly SeaWIFS).

SPACE STATION

Fourth, the strategic plan enables us to move aggressively, but sensibly, to build science instruments for the Space Station. This year, we will complete definition studies on our Space Biology Initiative (SBI) and begin the full development phase. The Space Biology Initiative provides for space hardware to conduct scientific research on Space Station Freedom. The facilities we are developing will be dedicated to space physiology, gravitational biology, exobiology, and closed ecological life support system (CELSS) testing and research.

We are also initiating the Biomedical Monitoring and Countermeasures (BMAC) program, an essential prerequisite to routine Space Station Freedom crew operations and a critical requirement for the implementation of human exploration activities in space. BMAC will enable us to determine ways to maintain optimum crew health and performance to medically certify repeated extended-duration tours of duty for space station astronauts.

The information and experience we gain through both the Space Biology Initiative and the Biomedical and Monitoring Countermeasures program will enable us not only to maximize our utilization of the Space Station, but will also help us to understand and meet human needs associated with future manned exploration missions.

RESEARCH BASE

Fifth, the strategic plan ensures a vital and productive research base. Our 1991 budget provides for the on-going support of thousands of researchers and students to acquire and analyze data from previous missions. This year we will also expand the research base with the initiation of 3 Life Sciences Specialized Centers of Research and Training, and the introduction of the multi-disciplinary Origin of Solar Systems Program.

SPACE EXPLORATION INITIATIVE

In support of the President's major exploration initiative in the 1991 budget, OSSA has developed a separate Space Exploration Initiative (SEI) strategy which supplements our existing base program strategy and clearly focuses our attention on this important national undertaking.

The Office of Space Science and Applications has an important scientific role to play as NASA expands its efforts to send humans back to the Moon and "on a journey into tomorrow" with a piloted mission to Mars. OSSA's support for SEI in FY 1991 can be characterized as a combination of: 1) on-going program activities, such as the Mars Observer to be launched in 1992 and elements of our Life Sciences program; 2) enhancements to the core program, including Mars Observer ground systems and software enhancements; and, 3) new initiatives, specifically the Lunar Observer and a series of satellites, known as Lifesat, to study the biological effects of space radiation.

SEI enhancements and initiatives to the OSSA program build logically upon our current programs and capabilities, as we work to address the requirements already identified through the agency's recent 90-day Exploration study, as well as requirements to be developed in the future. Our OSSA Space Exploration

Initiative strategy focuses on three major programmatic themes: meeting human needs; robotic exploration; and, in-situ science.

MEETING HUMAN NEEDS

Both the Space Biology Initiative and the Biomedical Monitoring and Countermeasure program, supporting Space Station utilization, will make significant contributions to our goal of understanding how to make it possible for humans to undertake long-term missions to the Moon and eventually Mars.

In addition to these important programs supporting OSSA's baseline strategy, we are also planning for a series of reusable satellites called Lifesat, designed to study the effects of space radiation on biological systems. Our full understanding of these effects is an important prerequisite for long-term human spaceflight. Lifesat will help us to: 1) determine radiation constraints for long duration human presence in space; 2) measure the biological response to the space radiation spectrum; 3) determine the synergy between radiation and microgravity effects; 4) test important pharmaceutical and gravity countermeasures; and 5) facilitate the establishment of acceptable risk levels. This year, we will complete satellite and payload definition studies, in order to begin development in 1992.

ROBOTIC EXPLORATION

NASA's strategy for exploration of the Moon and Mars will include both robotic and human missions. OSSA's robotic exploration efforts will: 1) provide for the enhancement of the Mars Observer ground data and software systems; 2) add the Mars Balloon Relay Experiment to the Mars Observer science payload to support selection of future landing sites; and, 3) preserve the 1996 launch opportunity for the Lunar Observer, with plans to begin the procurement of long lead-time parts in 1991 and full development in 1992.

As an element of the core strategic plan, OSSA has had under study a number of future space science missions, including the Lunar Observer, a one to two year mapping mission of the Moon in lunar polar orbit to provide a global scientific data base of the Moon. Within OSSA's new Space Exploration Initiative Strategy, Lunar Observer is identified as our highest priority SEI robotic mission. In order to provide timely support for future human activities on the Moon, and preserve our ability to launch as early as 1996, development for the Lunar Observer should begin in FY 1992. The Lunar Observer mission will measure globally the chemical and mineral composition of the Moon's surface, determine surface topography and landform, measure the Moon's magnetic and gravitational fields -- providing first rate science data and facilitating the selection of future landing sites for human missions.

IN-SITU SCIENCE

With the Space Exploration Initiative, there are new opportunities for conducting exciting science on and from the Moon and Mars. This year, we will work with the Office of Aeronautics, Exploration and Technology to begin developing strategies and identifying advanced technology development priorities to take full advantage of these opportunities. We plan to solicit recommendations from our Exploration Science Working Group, the discipline subcommittees of the Space Science and Applications Advisory Committee, and the Space Studies Board to assure that all promising candidates for in-situ science are given full and careful consideration.

PROGRAM CONCERNS

I would like to emphasize one other critical element of the Space Science and Applications program, namely the NASA institution -- its people, facilities, and resources. The American people expect, and our laws require, NASA to deliver a first class civil space program. To fulfill our obligation to its citizens, our country must recognize that this requires adequate funding to 1) hire and retain scientists, engineers, and managers to lead our world class science and applications programs; 2) develop and build world class R & D facilities; and, 3) provide resources to adequately manage world class programs from coast to coast and around the world.

As stewards for this Nation's future in Space Science and Applications, we take these institutional commitments seriously. We are working to optimize today's resources as we seek to assure an adequate pool of scientists, engineers, and forward thinking individuals capable of leading us across the space frontier, and into the future.

We are making real investments today in our future workforce, through innovative educational partnerships like the Graduate Student Research Program and the Joint Venture in Education (JOVE) program. For example, JOVE pairs university faculty and their students with working NASA scientists and engineers. NASA provides hands-on exposure to its personnel, facilities, and scientific mission data; in exchange for a commitment from the participating university to conduct research and analysis, and initiate outreach programs in their community.

SUMMARY

Mr. Chairman, the budget request that I have presented to you elicits three emotions:

The first is a sense of excitement for what this budget will accomplish. Between the flight of Magellan last May and the completion of FY 1991, we will launch more space science missions than in the entire decade of the 1980's. We will be awash in new data and new discoveries, and the world will marvel at our accomplishments. There will be no doubt that the space science program of the United States is the best in the world.

The second is a sense of responsibility. We know that we are affecting our global environment, but the changes we will bequeath to our children and our grandchildren are unknown. However, with Mission to Planet Earth and the entire global change research program of the federal government we will not let this ignorance persist. We will reduce the uncertainties in the global changes that will result from human interactions, so that we and future generations can take responsible actions to protect the future of the planet.

And finally, there is a sense of hope. The space program has a clear direction again. We are returning to the Moon, and then on to Mars, and there are efforts we must begin in FY 1991 to make that possible. Let the great adventure begin again, and never stop as we extend the human presence throughout the solar system.

Thank you very much.

Responses to written questions submitted by Chrm. Gore resulting from the May 10, 1990, hearing at which Dr. Fisk testified.

Budget Priorities

As I mentioned at our hearing, the budget request for the Office of Space Science and Applications has received a fairly healthy increase in the President's FY 1991 budget request.

Question 1: Dr. Fisk, in your view, what level of funding is required by the Office of Space Science and Applications to support a robust space science program?

Answer 1: The level of funding requested in the President's FY 1991 budget, $2,481.6 million, is required in FY 1991 by the Office of Space Science and Applications to support a robust space science and applications program.

Question 2: If the Committee is forced to look for savings in the FY 1991 authorization bill, how would you prioritize your space science research budget request?

Answer 2: Space science research programs are prioritized according to the criteria outlined in the Office of Space Science and Applications (OSSA) strategic plan. The strategic plan has been expanded this year to be responsive to two major Presidential initiatives, while preserving the integrity of OSSA's core programs. The fiscal year 1991 budget follows the five basic themes outlined in the OSSA core strategic plan, and also provides strong support for the U.S. Global Change Research Program and the Space Exploration Initiative.

OSSA's highest priority must remain the completion of its ongoing programs. Other first-order priorities in the FY 1991 budget request include funding the Earth Observing System (EOS), the cornerstone of the Global Change Program and OSSA's major new start candidate for FY 1991; Earth Probes, small missions critical to the success of the Mission to Planet Earth Program; Space Station Freedom Utilization, essential for assuring a science laboratory research capability in space; and the Research Base, the backbone of the Space Science and Applications program.

OSSA also assigns a high priority to ongoing and proposed space science programs essential to the Space Exploration Initiative.

Research Funding

Our second panel argued that because of economic realities and budget cutbacks, NASA has often had to choose funding spacecraft development schedules at the expense of Research and Analysis funding.

Question 3: In your view, has NASA achieved an adequate balance between funding Research and Analysis and scheduled requirements for spacecraft? What can be done to ensure that funds continue to be available for individual investigators, the backbone of space science research?

Answer 3: NASA continues to strive for an adequate balance between Research and Analysis (R&A) and scheduled requirements for spacecraft.

While augmentations or "fixes" have been made to NASA's budget requests in recent years to assure a healthy level of support for research and the "individual investigator," R&A budgets have been especially vulnerable to general reductions and budget sequestration.

The "choice" to fund spacecraft development at the expense of Research and Analysis is never an easy one. To ensure the availability of funds needed to support a vital research program, NASA will continue to work closely with the Congress, supporting the requirements of the Congressional budget process -- first, by aggressively seeking funding required to support a balanced and robust agency budget with adequate program reserves for flight project contingencies; and, by fully justifying and supporting all funding requests.

Question 4: Another concern raised was that large NASA missions are being conducted without adequate program contingencies, forcing funding reductions for Research and Analysis, which falls disproportionately on university researchers. What can be done to ensure a steady flow of funds to these university researchers?

Answer 4: In answer to the concern that large missions are being conducted with inadequate reserves:

While extreme circumstances -- like the two-year delay in Shuttle flights resulting from the Challenger accident -- may severely strain our ability to maintain adequate program contingencies, NASA has developed approaches for dealing with the uncertainties of cost estimation for major research and development missions, where original assumptions are subject to frequent changes and advances. OSSA is fully committed to managing its programs responsibly and effectively.

We attempt to quantify the uncertainty factors and then to apply appropriate levels of reserve to the project to provide for both unforeseen problems and assumptions that prove to be erroneous during the development cycle. In addition, appropriate reserve accounts are established and allocated for each element and sub-element of each program. Confirmation reviews are conducted following the instrument definition phase to assure retention of appropriate levels of and time phasing of reserves.

With regard to ensuring a steady flow of funds to university researchers:

OSSA recognizes that universities play a critical role in the United States space program, both as principal sites of research and as the source of the next generation of trained professionals to meet NASA's and the nation's needs.

In general, the Agency's recent support for universities has been substantial. For example, total NASA funding to United States universities was approximately $465 million in fiscal year 1989 and is projected to approach $500 million in fiscal year 1990. NASA will be funding at least 500 graduate student fellowships under the Graduate Student Researchers Program in 1990, and several new related efforts such as a fellowship program for students seeking advanced degrees relevant to Earth system science are being initiated. Furthermore, NASA expects to expand several university programs such as the University Space Engineering Research Centers sponsored by the Office of Aeronautics, Exploration and Technology, the Joint Venture in Education (JOVE) program sponsored by the Office of Space Science and Applications, and the National Space Grant College and Fellowship program.

In looking ahead, the President's fiscal year 1991 budget would ensure that research and analysis funding would recover from the setbacks of 1989 and 1990.

NASA and Economic Conversion

I am also a member of the Armed Services Committee, and this year we are trying to decide how and how much to cut the Defense budget. Whatever the final number is for the DOD budget, there are going to be major cutbacks at many high-tech defense contractors. As this economic conversion takes place, I would presume that there is going to be an upsurge in interest in NASA contracts among the contractors.

Question 5: In the past, DOD R&D funding has helped keep the U.S. at the leading edge in aerospace, electronics, advanced materials, and other critical technologies. Unfortunately, as the DOD budget shrinks, research may be the first to go. Do you see NASA doing more to push technology development, not just for NASA, but for all of United States industry?

Answer 5: The goal of NASA's space research and technology program is to develop advanced technologies that enhance or enable our Nation's future space missions. The goal of NASA's aeronautics research and technology program is to develop advanced technologies to enhance the U.S. economic competitiveness, ensure a safe and effective air transportation infrastructure and maintain a strong national defense. These programs will continue to ensure U.S. preeminence in aeronautics and space activities. To achieve these goals, NASA conducts a broad-based research activity to advance the state-of-the-art in technology at the concept, subsystem, and system level. The technology programs are implemented as a national partnership among NASA laboratories, industry, universities and other governmental organizations. We do not foresee changing the goals or approach of the NASA research and technology programs as a result of the changes in the Department of Defense budget.

We believe that the FY 1991 NASA budget request will provide increased opportunities which will contribute to keeping the U.S.

at the leading edge of technology. Initiation of ambitious programs such as the Earth Observing System and support for the President's Space Exploration Initiative will drive the development of numerous advanced technologies and industries within the U.S. Investment in a strong aerospace research and technology program will inherently strengthen the technology foundation and infrastructure of U.S. industry.

Question 6: Is NASA's budget large enough to really help defense contractors make the jump to the civilian sector?

Answer 6: In responding to the question, it is important to note at the outset that the NASA budget increase proposal for FY 1991 was not based on the presumption of providing new work for defense contractors. It is also important to keep in mind that many defense contracts as already perform work for NASA as well, so that much of the shift is really a change in workload mix within large contractors, rather than a complete change in the contractors; line of business.

Question 7: Do you think NASA will see increased support from industry because of the cuts in the DOD budget?

Answer 7: If there is a draw-down in DOD research and development funding, one can assume that formerly DOD related industry capabilities will be available for other applications. One can reasonably expect industry to seek additional opportunities with NASA.

NASA and Education

At the hearing, I discussed the role of the University of Wisconsin in developing the High Speed Photometer, one of the key instruments for the Hubble Space Telescope. We learned at an earlier hearing that over 100 students contributed to this project, and that while this is a research program, it had an important side benefit. Working on the Hubble Telescope educated and motivated these students like no lecture course could. I think this kind of linkage between research and education is critical, and I would like to see NASA encourage more of it.

Question 8: When deciding whether to award a contract for a particular instrument to a private contractor or to a university, is any consideration given to the educational benefits of having the work done in a university?

Answer 8: Contract awards for instruments must be made on the basis of merit, in a competitive proposal process, that judges technical suitability as well as cost. However, NASA recognizes the important additional educational benefits derived when work is done in a university setting and is pleased when universities take the opportunity to provide students with hands-on learning experiences. The majority of peer reviewers who evaluate space science research proposals are drawn from academia, and when averaged for the whole space science program, the majority of scientists involved in NASA's space science program are based at U.S. universities.

Question 9: Legislation has been introduced in the Senate that would authorize the Administrator to make grants to students and nonprofit organizations in an effort to increase interest in math, science, and engineering. S. 2567 is also aimed at attracting high school students -- who intend to teach -- into taking classes in space and earth sciences. Have you had an opportunity to review this legislation yet? Do you have any reaction to it?

Answer 9: NASA has reviewed S. 2567 and agrees with the goal to strengthen education in the fields of mathematics, science and engineering as authorized in the bill. We appreciate the recognition that S. 2567 gives to the role that NASA plays in math, science, and technology education. Our education budget is not large, but the unique aerospace content of our education programs provides great popular appeal. This and the participation in our programs by the professional education community makes our programs stand tall among all of the Federal agencies that conduct science and education outreach programs.

However, since such legislation calls primarily for grants to be awarded to students and other educational institutions, NASA believes that such a program might be better designed administered, and coordinated by the National Science Foundation due to their experience and operation of similar grant programs.

NASA's existing educational programs currently meet the interests of many aspects of the bill. For example, each year, in cooperation with the National Science Teachers Association (NSTA), approximately 200 elementary and secondary teachers of science, mathematics and technology attend workshops during the summer at out NASA field centers. Our 21 Designated Space Grant Colleges/Consortia receive $100,000 each to support undergraduate and graduate fellowships in NASA related fields. In addition, some of our Space Grant Colleges/Consortia are hosting workshops as exemplified by the recent Hubble Space Telescope Workshop sponsored by the Johns Hopkins Space Grant Consortium involving approximately 300 teachers.

Education and NASA Missions

I really feel that we need to plan the educational part of a mission from its inception. NASA could develop curricula that would allow students to trace the development of a mission from its beginning. When a program like CRAF-Cassini is approved, NASA could develop teaching materials for elementary school students describing the CRAF-Cassini and its mission as part of lessons on the Solar System. Then, a few years later, when the students are in junior high school and the hardware for the mission starts to get built, there could be lessons on engineering and instruments that go into the system. Finally, when the mission is launched, and the students are in high school, they could see the data coming in and learn how it is analyzed. With an integrated program like this, the mission would serve as a thread tying together science lessons on the Solar System, engineering, physics, and much more. It would add an extra element of excitement to learning, and it would give students a sense of ownership in NASA's programs. I think the educational benefits would be enormous.

Question 10: How much would such an effort add to the cost of a mission like CRAF-Cassini?

Answer 10: NASA has begun a pilot series of CRAF-Cassini Educational Workshops aimed at high school and middle school student and teacher pairs.

The experimental objectives of the program include: 1) to test the effectiveness of inviting student/teacher pairs, rather than either group alone; 2) to give the participants a better behind-the-scenes understanding of a mission by allowing them to study and follow it through the design stage, rather than in flight or after completion; and, 3) to track students through the next six or more years as they choose career paths.

The pilot program is now in its second year. Recently, 24 pairs of high school students and their teachers participated in a week-long workshop at NASA's Johnson Space Flight Center in Houston. During the workshop, participants learned more about the program from key NASA and JPL managers, who discussed CRAF-Cassini's science objectives, mission design, system engineering, program developments, and special investigations. The workshop also focused on the development of curriculum for the classroom, education opportunities in Aerospace in Texas schools, and special interactive learning exercises.

The cost for this educational pilot is not additive to the overall cost of the CRAF-Cassini mission. NASA's CRAF-Cassini project office provides minimal financial support for this pilot program (No more than $10 thousand per year). This support is leveraged with funding from NASA's Education Affairs Office, and recently, funding from space grant colleges. Funding requirements will need to be reassessed when this program moves beyond the pilot stage.

The major investment made by NASA's program and project offices is one of time and expertise, rather than money. The scientists, engineers, and managers for CRAF-Cassini have a vested interest in capturing the attention and channeling the enthusiasm of both students and teachers, so that we can ensure a future workforce capable of using CRAF-Cassini, analyzing the data it will return, and uncovering the mysteries of Saturn, Titan, comets, and the possible origins of our universe.

The CRAF-Cassini Educational Workshop is just one element of NASA's multi-faceted educational program.

Question 11: Has anything like this been tried for Voyager, Viking, the Hubble Telescope, or other major NASA missions?

Answer 11: NASA's Educational Affairs Division has conducted programs for students and teachers and produced classroom materials for Voyager, Viking, and the Hubble

Telescope. Programs are also planned for upcoming missions such as Astro-1. These programs have generally been designed to expose students and teachers to mission objectives after they have been developed, rather than during the mission design stage. The CRAF-Cassini pilot workshops will be carefully evaluated to see if this is going to be a feasible model for future mission-related, educational programs.

Question 12: How about Mission to Planet Earth? How are you going to encourage educational spinoffs from that program?

Answer 12: As with other space missions, EOS and other Earth science efforts over the next few years will encourage young people to take up science and math with a concrete goal in mind -- working for the Earth.

Because of its strong emphasis on science and data analysis, EOS funding will effectively double the research community that will dedicate itself to understanding global change. Support of this kind will help universities across the country, and around the world, to develop programs in Earth science study and analysis. Such programs will, in turn, train the next generation of Earth scientists.

We also believe Mission to Planet Earth can play a significant role in educating the public, and particularly the young, about the importance of understanding the Earth's processes. As with other space missions, EOS will help to encourage young people to pursue studies in science and math with a concrete goal in mind--working for the Earth.

As you know, Mission to Planet Earth is also one of the primary themes of International Space Year in 1992. A number of educational programs are being planned around the world to take advantage of this celebration of the Space Age. Some of the programs under development will include Earth observations -- providing students the opportunity to work with remotely sensed data and ground truth surveys. These programs are being planned both internationally and nationally and we will be happy to provide you or members of your staff with additional information as the programs are further developed.

We have already taken a step forward in developing the next generation of Earth scientists with the first awards of the Global Change Fellowship Program on June 22, 1990. The Global Change Fellowship Program is designed to support students pursuing doctoral degrees in specific Earth science research areas. The 37 selected students represent 28 U.S. institutions of higher learning.

Question 13: Are there any efforts to reach not just students, but adults as well?

Answer 13: NASA has begun a process to update and convert the existing Five-Year Educational Affairs Plan into a ten-year plan. In this way, the plan will correspond to the time frame of the President's national education goals for the 1990-2000 decade. Adults in the general public represent one of the principal education audiences that would be targeted under NASA's new educational initiatives, entitled Science and Technology Literacy for the 21st Century (STL-21). Increasing the educational involvement and scientific literacy of parents and other adults will have a positive effect on efforts to increase the scientific and technical literacy of parents and other adults will have a positive effect on efforts to increase the scientific and technical literacy of the Nation's students. We will be looking to models similar to the way the U.S. Space Camp in Huntsville, Alabama, has added a space academy for adults.

Nuclear Reactors and Space Science Observations

I understand that the Soviet reactors in orbit emit gamma rays which hinder satellite observations of gamma rays. Recently, a Japanese satellite was rendered useless because of spurious signals from the Soviet satellites.

Earth Observing System

Dr. Fisk, as I have said many times, I believe that the Earth Observing System is a very important project and is badly needed to better understand and predict global environmental change. We discussed EOS in some detail at an earlier hearing, but I want to focus on several points at today's session as well.

Question 14: The congressional budget process has begun its incremental movement toward the new fiscal year, as both the House and Senate Budget Committees have recommended that the President's request for NASA be cut by about $1 billion. In your view, where should EOS be in terms of NASA's funding priorities?

Answer 14: The President made a strong commitment to NASA and to the U.S. Global Change Research Program in his FY 1991 budget. The Earth Observing System (EOS) and the Earth Probes program, both key elements of NASA's Mission to Planet Earth, are both Presidential initiatives with strong Administration and agency backing. Moreover, the role of NASA within the USGCRP is clearly to provide the essential space observations necessary to better understand the nature of our Earth and of global change. Within NASA, EOS is a high priority, because of its designation as a Presidential initiative. Within the Office of Space Science and Applications, EOS is the significant new start for FY 1991, intended to maintain U.S. leadership in space science. However, both for the agency and OSSA, it would neither be correct nor prudent to assume that retaining EOS can or should mean making cuts in other important agency programs.

According to the OSSA Strategic Plan, the timely completion of ongoing missions represents the highest priority for the office. Similarly, at the agency level, the safe operation of the Space Shuttle system, along with the completion of the Space Station and other important ongoing programs, must represent the highest priority for the agency. We believe that the request for EOS, and the other elements of Mission to Planet Earth, is a reasonable and wise investment for the United States to preserve our leadership on this important issue, and to acquire the understanding of the Earth needed to guide policy makers in the future.

Question 15: What reductions did the Office of Management and Budget make to NASA's FY 1991 request for EOS?

Answer 15: NASA's FY 1991 budget request to the Office of Management and Budget (OMB) for EOS was $188 million (not including funds for the first EOS polar platform, which were originally budgeted under the Space Station Freedom). We feel that the President's budget makes a strong commitment to EOS and the U.S. Global Change Research Program.

Question 16: While the fate of Landsat 7 currently lies with the National Space Council, assume for a moment that data from Landsat will continue to be collected over the next several years. What will Landsat's role be in relation to the Earth Observing System?

Answer 16: Several of the instruments proposed for inclusion on the EOS platforms will provide land remote sensing built upon the heritage developed in the Landsat program. Indeed, the first EOS platform will likely include several surface imagers, such as the Moderate Resolution Imaging Spectrometer (MODIS), the High Resolution Imaging Spectrometer (HIRIS), and the Intermediate Thermal Infrared Radiometer (ITIR) being developed by the Japanese. These imagers will offer the next generation of surface observations, building on the extensive set of observations made through the Landsat program.

The Landsat imagers are the natural precursors to the EOS instruments mentioned above. The ability to make extensive use of Landsat data, perhaps by including it in the EOS Data and Information System (EOSDIS), would give researchers a far clearer picture of the changes which have taken place on the Earth. The ability to compare images over such an extensive period of time would be of significant scientific value. If the Landsat database were to be made readily available to researchers today, it is likely that scientists would be able to learn a great deal in advance of the flight of the polar platforms, thus allowing their analysis to be incorporated in the specific targeting and observations to be made as a part of EOS. Unfortunately, the current pricing system for Landsat data would make it prohibitively expensive to include any more than a small subset of Landsat data in the EOSDIS.

EOS Data and Information System (EOSDIS)

A key to the success of EOS and NASA's Mission to Planet Earth will be the successful development of EOSDIS -- a state-of-the-art data and information system that is expected to be capable of processing, storing, and disseminating huge amounts of data from existing and future earth science missions.

Question 17: What technological advances are necessary to ensure the success of EOSDIS? What must be done between now and 1994 to get EOSDIS up and running?

Answer 17: The EOS Data and Information System (EOSDIS) is one of the most important elements in the EOS Program. NASA is committed to providing the resources necessary to acquire the hardware and data management systems, and to improving those systems, as technology advances, to make EOSDIS an ongoing success.

The risk that critical technologies will be unavailable for use by the EOSDIS is fairly low. The EOSDIS could be built today; though the absence of technology advances could result in the cost of the system exceeding the currently planned budget. We expect to achieve approximately two generations of computer technology advancement before the final elements of EOSDIS are operational, and the system only requires one generation of improvement to meet the planned targets.

Though we do not expect that they will be needed, we have identified potential backup approaches in the event that critical technologies are not available. These include: possible degradation in the timeliness of data searches and other user services; decreases in the number of standard products which are routinely produced when the requisite EOS instrument data is available; increasing the amount of time allowed for data reprocessing; and running models at lower resolution. Storage and networking technology are the key areas where technology advances are needed, and both are currently experiencing rapid capability growth driven by the commercial marketplace.

NASA is taking a variety of steps to insure that EOSDIS operates in an efficient, effective, and open fashion. The EOSDIS will include the extensive use of easy electronic access, early prototyping, and strong science user community involvement in the system design, review, and implementation. As technologies improve, the EOSDIS baseline provides for upgrades of the EOSDIS hardware every five years.

Much of what must be done before 1994 involves the organization of the distributed architecture of the EOSDIS, along with some equipment purchases related to the system. A priority is to link the various distributed active archive centers (DAACs) together into a responsive data system, complete with interactive directory and scanning capability. Numerous existing data sets are being reformatted for inclusion in the EOSDIS, which will permit scientists to produce new data products from these data sets in the near term, while also gaining valuable experience with the data system. Their experience, in turn, will allow EOSDIS architects to improve the system to make it more responsive and useful for the research community. The EOSDIS Request for Proposal (RFP) is expected to be issued in late 1990, with final selection of a Phase C/D development contractor expected in late 1991.

Question 18: Has the science community been involved in the development of EOSDIS, thereby ensuring that it will meet researcher's needs?

Answer 18: As with all aspects of planning for EOS, scientists have played a major role in the planning for the EOS Data and Information System (EOSDIS). At every stage of planning, through the NASA advisory committee system and through various committees, panels, and boards associated with the National Academy of Science (specifically through the National Research Council) and NASA Advisory Council, scientists have had the opportunity to review and comment on the basic plans for EOS, the polar platforms, and the data and information system. The open architecture design for the EOSDIS reflects the strong requirement of the science community that the system be easy to access and use.

The EOS Data and Information System (EOSDIS) will be brought on-line by 1994 to facilitate the distribution, analysis, and archiving of data from past missions, as well as information from the numerous precursor missions that will fly in advance of the EOS platforms. These efforts will both insure that we derive maximum information from existing and upcoming data, and that we have adequate experience with handling the data in advance of the larger data flows from the EOS platforms. Scientists will have an opportunity to use the EOSDIS to better assess and reprocess data from earlier missions, thus allowing them to gain crucial experience with the system in advance of the large quantity of data expected once the EOS platforms are launched. This experience will help engineers to perfect the system and make changes and improvements recommended by the scientists.

Question 19: At our hearing on Mission to Planet Earth last month, Dr. Tilford, who was accompanying you, said that because of its complexity, Landsat would likely be the last global data set to be included in EOSDIS. What does NASA need to be able to include Landsat data in EOSDIS?

Answer 19: Most of the Landsat data is stored at the EROS Data Center (EDC) in South Dakota, which is operated by the United States Geological Survey (USGS) as the principal U.S. processing, distribution, and archive location for U.S. satellite land remotely sensed data. In March 1988, NASA and USGS signed a Memorandum of Understanding (MOU) establishing the EROS Data Center as the "active short and long-term archive for experimental land remotely sensed data obtained by NASA" including a large amount of the data "from the EOS program and other current and future experimental systems." This essentially established EDC as one of the primary data centers for the proposed EOS Data and Information System (EOSDIS). The MOU also included USGS in the planning process for EOSDIS, a role which has become more important as discussions on EOSDIS architecture and organization increase.

NASA and USGS agreed to the first clarification to the MOU in September 1989. This document spelled out in more detail the specific EOS instruments whose data would be archived at EDC and resolved a number of other procedural questions regarding EDC responsibilities for EOSDIS. In essence, EDC has become a functioning member of EOSDIS project management, with the EDC Deputy Director attending all EOSDIS project reviews.

The Landsat satellite series provides a unique U.S. source of remotely sensed land data measurements. In 1984, the Land Remote Sensing Commercialization Act commercialized the operation of the Landsat system, including the marketing, sale, and distribution of data. Though NASA no longer has oversight authority for the program, we are a customer of Landsat data and maintain liaison with NOAA and the Earth Observations Satellite Company (EOSAT) in the planning for future systems.

Incorporating Landsat data at EDC into the EOSDIS would require a fundamental change in the Land Remote Sensing and Commercialization Act of 1984. That Act places responsibility for marketing the data, both to the government and private users, in the hands of the EOSAT Corporation. The current pricing policy for Landsat data is such that it is often too expensive for use by individual researchers, and can even be a significant financial burden on research programs. As a consequence, much of the data has not ever been processed into higher order data products, which might be helpful in plotting trends and performing sophisticated analyses. In this regard, it would take time for researchers to review this large data set and to reprocess it into a form that would be readily accessible by the EOSDIS. However, extensive use of Landsat data, such as would be required to incorporate the data set into the EOSDIS system, is simply beyond the current funding of the EOS program. Either a change in the scope of the current Act or a change in the pricing policy by the EOSAT Corporation would probably be needed to include Landsat data in the EOSDIS.

NASA and Networks

As you know, I introduced S. 1067, the National High Performance Computing Act, to ensure that the U.S. maintains its lead in supercomputing and computer networking. I think it is especially critical that we develop and effectively utilize high-speed, fiber-optic computer networks capable of transmitting gigabits of data, billions and billions of bits, every second. The bill calls for creation of the National Research and Education Network, which would link researchers and other throughout the country.

Question 20: I've been told that while we are on the seventh generation of supercomputer, we are still relying on second-generation computer networks. Supercomputers can generate billions of bits of data a second, but networks can only transmit a million or two. There seems to be real mismatch here. How serious is this mismatch? What could we do with a national gigabit network?

Answer 20: To date, NASA's current science networks have been providing satisfactory service to the vast majority of space science researchers at up to one million bits of data per second. However, requirements for faster throughput are becoming more urgent as a result of new missions such as Galileo, UARS, and the Hubble Space Telescope. In addition, the population of active scientists is growing in number and in geographical distribution, and the workstation technologies becoming available to them are approaching supercomputer capacities. In this environment, the benefits of a National Education and Research Network (NREN) could include; significantly greater capacity between NASA facilities and science research institutions, improved interactive access to supercomputing resources to enhance science productivity, greater access to researchers distributed across the nation, and more opportunities for commercial provisioning of these services.

Question 21: Is enough work being done to develop the technology needed for gigabit networking? Who's doing most of the R&D? Could we move more quickly in this area?

Answer 21: In accordance with the National Research and Education Network (NREN) approach suggested by the Federal Coordinating Council on Science, Engineering and Technology, most gigabit network research will be performed by the Defense Advanced Research Projects Agency (DARPA). NASA and other agencies will work with DARPA to support this and other objectives of the High Performance Computing (HPC) program. For example, NASA is working with DARPA to develop satellite augmented networks based on ACTS technology. The science missions of the Office of Space Science and Applications (OSSA), working closely with the technology development programs of the Office of Aeronautics, Exploration and Technology (OAET), will continue to take advantage of these network technologies as they mature.

Question 22: Will we be able to transmit the high flows of data that EOS and similar missions will generate? Or will scientists have to rely on Federal Express if they want to share their data?

Answer 22: NASA's approach to accommodating high data volumes seeks to arrive at a cost-effective balance between available communications technologies and alternate delivery mechanisms. High speed networks using satellite and terrestrial facilities like the NREN, and technologies such as CD-ROM optical disks will be employed to meet future data dissemination and data transfer requirements.

Question 23: What about storing all this data? What advances will be needed in data storage technology? Are we moving ahead quickly enough in this area?

Answer 23: Systems being developed by the commercial television and audio industry will provide high quality, high capacity digital storage on magnetic tape, both for large volume archiving and data distribution. These systems are likely to represent a major advance over today's conventional computer tape techniques, and are a practical alternative for projects such as EOS. High capacity optical disk technology also offers considerable promise for archival storage. However, proof of the long term reliability of the media and establishment of widely accepted industry standards are necessary before it can be used for EOS data storage. These technologies are expected to be ready in time for the EOS program.

Nuclear Power

The use of nuclear power in space has been a highly controversial issue in the past year, as the October 1989 launch of the Galileo Jupiter probe focused widespread public attention on the risk of radioactive release in a launch accident or reentry accident. This will soon be an issue again, as the nuclear-powered Ulysses spacecraft is scheduled to be launched in October.

Question 24: Has NASA conducted a risk analysis of the possible accidental release of radioactive materials from the Ulysses spacecraft?

Answer 24: Yes. NASA has conducted extensive risk analysis associated with the possible accidental release of radioactive materials from the Ulysses spacecraft. Intensive analysis indicates that the risk of any such release is small. Even in the rare event of a release, comprehensive analysis indicates that the chances of adverse health or environmental consequences are remote. No accident scenario during any phase of the Ulysses mission, to a probability level of one in one million, would lead to a fatality. A comprehensive description of the risk analysis performed and the results obtained are available in the Ulysses Final Environmental Impact Statement (FEIS) published for public inspection in June.

Question 25: How does the safety risk of Ulysses compare to that of Galileo?

Answer 25: It is difficult to make direct comparisons between the safety risks associated with the Ulysses and Galileo missions, given the differences in mission profiles. While a specific comparison of statistical models and probabilities is not particularly meaningful, in general, the safety risks associated with Ulysses are smaller than those predicted for Galileo, since Ulysses uses one nuclear power source instead of two, and does not fly on a trajectory requiring Earth fly-by gravity assists.

Nuclear Reactors and Space Science Observations

I understand that the Soviet reactors in orbit emit gamma rays which hinder satellite observations of gamma rays. Recently, a Japanese satellite was rendered useless because of spurious signals from the Soviet satellites.

Question 26: How serious is this problem and how will it affect the Gamma Ray Observatory?

Answer 26: It is our understanding that the Japanese satellite, Ginga, lost significant amounts of data on gamma-ray bursts because its computer memory was swamped by transient events from two Soviet satellites, Cosmos 1818 and 1867, in 1987 and 1988. Other observations by this satellite were not affected as severely.

It appears that the interference with scientific satellites only occurs when the reactors are in operation. To our knowledge there are no operating nuclear-powered satellites in orbit at the present time.

As long as no additional nuclear reactor-powered satellites are launched into Earth orbit, there will be no affect on the Gamma-Ray Observatory (GRO). How serious the affect will be if an operating reactor is orbited into Earth orbit during GRO's lifetime depends on several factors, including the number of reactors, their operational power and design, and their orbit. Past experience with NASA's Solar Maximum Mission (SMM) satellite suggests that Soviet satellites such as the Radar Ocean Reconnaissance Satellite (RORSAT) operating at altitudes of 260 km will not seriously affect GRO.

In contrast, individual systems flown at 800 km, such as on Cosmos 1818 and 1867, would interfere with GRO operations about 15 to 20 percent of the time. A method for determining when these interferences will occur has been developed. This will enable the individual experimenters to power down their instruments during these periods, if required by the interference.

Section 1012 of the 1990 Defense Authorization Act requests that the President submit a report to Congress on the potential for interference with gamma-ray astronomy missions that could be caused by space nuclear reactors in Earth orbit. An interagency panel is currently working on this report.

Question 27: A recent GAO report said that NASA underestimated the seriousness of the problem of space debris. What would happen if a large piece of space debris hit an orbiting nuclear reactor? How likely is that? (Is it safe to launch hundreds of reactors into orbit as part of Star Wars?)

Answer 27: The probability of a large piece of debris colliding with an orbiting reactor is extremely low. The host population of orbital debris in low earth orbit (LEO) as reported in February 1989 in the Report on Orbital Debris by Interagency Group (Space) for the National Security Council ranges in numbers as follows:

- for sizes greater than 10cm ~0.2%
- for sizes 1-10cm ~ 0.5%
- for sizes less than 0.1-1cm ~99.3%.

Most of the meteoroid mass in LEO is in sizes of about 0.01cm. Large pieces of space debris (10cm in diameter or greater) can be readily tracked in LEO, allowing collision avoidance by means of pre-planned orbital adjustments or by evasive maneuvering of the orbiting spacecraft. We believe that avoidance offers the most promising defensive strategy for future reactor operations in LEO.

Collisions with relatively smaller debris (<1cm) with an Earth orbiting reactor power system are being addressed in the DOE's space reactor system design efforts. If the mass and relative velocity of this potential collision debris were of such a nature as to cause a failure of the reactor's primary coolant system, a self-acting reactor protection system would shut down the reactor and an autonomous auxiliary coolant loop would then remove all the remaining heat from the reactor vessel. The reactor would remain intact in orbit, causing no harm to either the Earth's orbital or surface environments.

At the lower size range, penetrations by micro-size meteoroids and debris are precluded in current U.S. space reactor design considerations by the use of hardened protective materials. Specifically, this reactor protection will be provided by a carbon-carbon reentry shield and a radiation shield, by an armored primary coolant loop, and in addition, bumper material emplacements are applied on the systems' secondary or radiator coolant loops.

Question 28: Suppose the United States banned nuclear reactors from orbit. What impact would that have on NASA's space sciences program?

Answer 28: NASA has testified to Congress on space nuclear power development, future applications, and our concern that a ban on use of nuclear power sources in Earth orbit could significantly foreclose future mission operations. The very low solar intensity at the outer planets precludes the use of solar power for deep space exploration missions. The use of nuclear reactor power for on-board power and for electric propulsion is either very beneficial or required for missions to the outer solar system. To fully exploit the benefits to be gained from the use of electric propulsion, these planetary spacecraft are expected to be assembled, checked-out and deployed from Earth orbit. This will require the start-up of the reactor in earth orbit.

Although the primary operator of nuclear reactors in space is beyond earth orbit, an earth orbit reactor ban could prematurely foreclose opportunities. For example, commercial benefits from large-scale, microgravity materials processing facilities operating in low earth orbit, as well as benefits from large geosynchronous orbit communications platforms, enhanced capability air and ocean traffic control satellites and global observation and sensing platforms for which large amounts of power will be required. A compact nuclear reactor power source may well be the most practical power system option for such applications.

Question 29: What would be the impact of a total ban on the use of nuclear power in space? There has been discussion of using nuclear reactors to provide power for bases on the Moon. Are there alternative sources of energy?

Answer 29: We believe that the use of nuclear power is essential to the civilian space program; for example, a total ban on the use of nuclear power sources (reactor and isotope) would preclude the conduct of outer solar system missions. To support these solar system missions and the potential missions under consideration as part of the President's Space Exploration Initiative, the Space Research and Technology program has an aggressive technology development effort in both nonnuclear and nuclear space power sources. The nonnuclear activities include fundamental efforts in photovoltaic cells, arrays, batteries, power conversion and power management technologies. The nuclear power activities include both reactor and isotope sources.

The use of nuclear power sources is required to enable the missions being studied as part of the Space Exploration Initiative. For an initial lunar base, a solar-based system will likely be used and NASA's Exploration Technology program is developing photovoltaic and regenerative fuel cell technologies for this application. However, as the mission evolves, base power requirements will increase and nuclear power systems will be required. For example, in the case of an expanded lunar base with power demands of 100KW or more, our studies have shown that because of the weight associated with the energy storage system required to provide power during the 14-day lunar night, the weight of a solar power system would be vastly greater than a nuclear system. For a mature base, this would result in a launch weight savings of over a million pounds. In other cases, such as a proposed Mars base the use of nuclear power is either very beneficial or required.

We believe that future space nuclear reactors for a moon base can be developed and used in a manner that ensures the public health and safety as well as protection of the environment. This approach is wholly consistent with NASA's past and present practices regarding nuclear system development and operation.

Space Station Freedom

Later today, the Space Studies Board will raise its concern that in the current plans for the Space Station Freedom, there are no plans for either a dedicated Life Sciences Laboratory or focused space biology and medicine research.

Question 30: Can you comment on the status of plans for a Life Sciences Laboratory on Space Station Freedom? Is adequate attention be given to research on space biology and medicine?

Answer 30: Currently, there are no plans for a dedicated Life Sciences Laboratory on Space Station Freedom. Rather, the U.S., Japanese and European laboratories will each accommodate a mix of scientific payloads. Specialization of the laboratory elements was discussed during the Phase C/D negotiations with our international partners; however the concept was never agreed upon because each partner wanted to retain the option to conduct all phases of microgravity science within their laboratories. A dedicated discipline laboratory would have precluded that option.

Research on Space Station Freedom will include considerable life sciences work. Research in space biology and medicine will be carried out using hardware developed in the Space Biology Initiative (SBI) and the Biomedical Monitoring and Countermeasures (BMAC) programs. The SBI is providing hardware for the conduct of research on the Station in physiology, gravitational biology, controlled ecological life support systems and exobiology. The BMAC program will provide a complement of diagnostic and other equipment for monitoring physiological deconditioning of crew members. This research will enable us to determine methods to maintain optimum crew health and performance, and to medically certify crews for repeated extended duration tours of duty. The U.S. 2.5 meter centrifuge will provide a variable gravity research facility on Space Station that is unmatched in the world. The specifics of how life sciences research will be accommodated are currently under study.

Question 31: In broader terms, how important is the Space Station Freedom to the various Space Science and Applications programs?

Answer 31: Space Station Freedom utilization is a key part of Space Science and Applications programs, as evidenced by its prominence in the OSSA Strategic Plan. The most important opportunity the Space Station offers is the chance to perform long duration investigations in fully equipped pressurized laboratories with highly skilled science crews. This on-orbit time is critical to progress in the life and microgravity sciences. Also significant are the Station's accommodations for attached payloads, which will benefit the space physics, astrophysics, communications, solar system exploration, and Earth system science disciplines.

Cost Containment

In last year's Senate authorization bill, language was approved requiring NASA to submit a plan to limit the annualized and total estimated cost of the Comet Rendezvous Asteroid Flyby (CRAF) and the Cassini mission to Saturn. The combined funding limit for these two projects was subsequently set at $1.6 billion.

Question 32: Can NASA bring these two projects to completion within that funding limit?

Answer 32: NASA anticipates completion of both the Comet Rendezvous Asteroid Flyby (CRAF) and Cassini missions within the $1.6 billion funding limit. If it is determined during the course of this program that the total budget will exceed the planned resources, NASA will be prepared to descope the mission to fit within the funding limit as indicated in Public Law 101-144, dated November 9, 1989. In accordance with last year's Senate authorization bill, NASA will submit to Congress the first semi-annual status report on the CRAF/Cassini Cost Containment Plan this summer.

Question 33: In your view, do you think cost containment plans, such as the one that was proposed by this Committee, in any way hinder spacecraft development?

Answer 33: Cost containment plans, in principle, do not hinder spacecraft development. Such plans may, however, create additional challenges for the managers charged with their execution. For any plan to be effective, flexibility must be built in to ensure management's ability to exercise discretion in dealing with change, external constraints, and unforeseen events.

The three major variables for managing spacecraft development programs have always been cost, schedule, and content. When management discretion and flexibility is limited in any one of these areas, the likelihood for change or impacts to the other two variables increases.

ACTS

For the first time in five years, NASA has requested funds in its FY 1991 budget for the Advanced Communications Technology Satellite (ACTS). This $500 million satellite, which is scheduled for launch in 1992, calls for flight verification of advanced technologies that will enhance future commercial communications satellites.

Question 34: Some in the satellite industry have publicly questioned whether the technology to be tested on the ACTS satellite is worthwhile. What is your response to these concerns?

Answer 34: ACTS represents significant advances in communications technology. Key technologies developed in this program include electronically hopping spot-beam antennas, onboard processing and switching, Ka-band transmission, and dynamic rain fade compensation. These new technologies will improve the communications capabilities of the United States.

Perhaps the best evidence of the value of the technology is the fact that the commercial application of some ACTS technologies is already being planned. For example, Motorola, Inc., in cooperation with several other major satellite companies, is proposing to develop a global mobile phone service that would use the ACTS baseband processor technology it was responsible for developing under contract to NASA. The system, called Iridium, would use a network of satellites to relay radio-telephone calls anywhere on Earth. Also, Norris Satellite Communications has filed a request with the FCC to launch a satellite to provide both fixed and mobile communications services at Ka-band (30/20 GHz) in 1994. This new satellite will take advantage of satellite receiver designs and other equipment developed in the ACTS program. The willingness to invest significant funding commercially in these systems before the ACTS satellite is actually flown attests to Motorola's and others' confidence in the value of ACTS technology.

Question 35: In 1988, Congress imposed on overall cost limit of $499 million for the ACTS satellite. Where does the project stand in relation to this limit? Will there be any difficulty in staying within the cost limit?

Answer 35: The ACTS project cost remains within the $499 million cap. NASA does not foresee a change in the cost.

Responses to written questions submitted by Sen. Danforth resulting from the May 10, 1990, hearing.

Question 1: We in Congress have high expectations for the Hubble Space Telescope. We are told that it will allow us the view the remnants of the Big Bang that formed our universe some 20 billion years ago. It will explore our origin, our present, and our future. Have the difficulties with Hubble been resolved? Will Hubble revolutionize astronomy as we have been told? When will we see the first focused pictures of the solar system from the Hubble Space Telescope? How will the viewing time on Hubble be shared between private sector, university, government, and foreign users?

Answer 1: NASA has made significant progress in overcoming anomalies in Hubble Space Telescope (HST) operations. Only two anomalies remain unresolved:

- HST body rate excitation, the result of thermal changes experienced as HST crosses the terminator from day to night or from night to day, has been reduced from 6 arc seconds peak-to-peak during day/night transitions to 0.5 arc seconds. During quiet orbit periods, this excitation measures about 0.02 arc seconds. Pointing Control System control loop software modifications, which are expected to provide pointing stability that meets or exceeds design specifications, will be completed in early August.

- Recent tests suggest that HST is experiencing spherical aberration; that is, an inability to focus light into a single, precise point. Instead of focusing a stellar image so that 70 percent of its energy is located within a 0.1 arc second radius circle, HST is currently able to focus only 20 percent of the energy in that same area. NASA has established the Hubble Space Telescope Optical Systems Investigation Board, chaired by Dr. Lew Allen, Director of the Jet Propulsion Laboratory, to investigate this anomaly.

  In the interim, NASA will be reordering the scientific program for HST to take into account HST's current strengths. As a result, significant and unique spectroscopic and ultraviolet science and astrometry will be accomplished during the next few years.

NASA remains confident that HST will provide astronomers with an unparalleled vantage point from which to explore the mysteries of the universe. The discoveries made possible by HST are likely to alter fundamentally our understanding of the universe, and of mankind's place within it. HST's potential for revolutionizing astronomy and cosmology rivals the great advancements which followed Galileo's invention of the telescope over 400 years ago.

As stated earlier, HST's schedule for scientific activities is currently under review. Therefore, no exact date can be predicted for when first science images of celestial objects in our solar system will be processed and available for distribution.

No exact ratio of viewing time allotted to private sector, university, government, and foreign users has been calculated. Viewing time on Hubble is determined through the scientific peer review process in which proposals were evaluated on the basis of scientific merit and technical feasibility by a panel of experts. Observation time is divided among three general categories: Guaranteed Time Observers (GTO's), General Observers (GO's) and housekeeping activities. A small part of the time reserved for housekeeping has been set aside by the Space Telescope Science Institute for amateur astronomers. All three categories include individuals from each of the groups mentioned.

Question 2. Many of our colleges and universities rely on the Research and Analysis (R&A) account to fund research grants and projects important to their space science programs. The planetary materials research at Washington University is funded such a NASA grant. However, in recent years, money from the R&A account has been used to compensate for shortfalls in other programs. The transfers from the R&A account have had an enormous impact on the universities' programs. How much money has been transferred from R&A in recent years and what were the reasons for the transfers? What can be done to minimize such transfers in the future?

Answer 2: There have been two consecutive years when planetary R&A funding has been reduced significantly, FY 1989 and FY 1990. In one of these years, however, funds were transferred directly from R&A to compensate for shortfalls in other activities within the planetary exploration program. Specifically, in FY 1990, $4.4 million was transferred from R&A to cover unbudgeted costs of accommodating a French-provided antenna on the Mars Observer spacecraft in order to relay science data acquired by Mars balloons released from the USSR Mars 1994 spacecraft.

We believe that the problems in FY 1990 have been heightened by a combination of factors that we have not had to cope with simultaneously in previous years. These factors include the FY 1990 application of across-the-board reductions to meet Gramm-Rudman targets and to fund the Federal war-on-drugs effort.

Given the critical importance of maintaining flight schedules and assuring the delivery of planetary spacecraft on time for launch during dynamically constrained, infrequent flight opportunities, the FY 1990 Gramm-Rudman reductions could not be imposed on the planetary flight programs or missions under development. Therefore, a disproportionate share of planetary Gramm-Rudman targets and war-on-drug taxes had to be met by taxing R&A and Mission Operations and Data Analysis funds. The reduction to the R&A budget was approximately $4.1 million.

The reduced level of R&A funds in FY 1989, on the other hand, was a direct consequence of a Congressional directive to reduce planetary program funding by $10 million. Since funds for developing spacecraft cannot be reduced without severe cost and schedule risks, this reduction was taken in the R&A and Mission Operations and Data Analysis programs. The R&A reduction was approximately $8 million.

While these explanations underscore the fact that the reductions in planetary research funding were not planned, they were nonetheless real. The universities play a critical role in the United States space program, both as principal sites of research and as the sources of the next generation of trained professionals to meet NASA's and the nation's needs.

In general, the Agency's recent support for universities has been substantial. For example, total NASA funding to United States universities was approximately $465 million in fiscal year 1989 and is projected to approach $500 million in fiscal year 1990. NASA will be funding at least 500 graduate student fellowships under the Graduate Student Researchers Program in 1990, and several new related efforts such as a fellowship program for students seeking advanced degrees relevant to Earth system science are being initiated. Furthermore, NASA expects to expand several university programs such as the University Space Engineering Research Centers sponsored by the Office of Aeronautics, Exploration and Technology, the Joint Venture in Education (JOVE) program sponsored by the Office of Space Science and Applications, and the National Space Grant College and Fellowship program.

In looking ahead, with specific attention to the planetary sciences, the President's strong fiscal year 1991 budget would ensure that planetary science funding would recover from the setbacks of 1989 and 1990.

Question 3. There is an ongoing debate about the relative merits of "big" science (Mission to Planet Earth, the Superconducting Supercollider, for ex.) versus "small" science. Within NASA's space science budget request, is there balanced support for both big and small science?

Answer 3: Yes. The NASA space science budget request recognizes the importance of maintaining a balance between small, moderate, and major space science missions. While there is a limited cadre of small missions given the constrained funding situation, an adequate balance of small, moderate, and major missions exists.

A representative sample of small missions includes the Small Explorers program, Earth Probes, sounding rockets, balloons, and high altitude aircraft experiments. "Big science" programs, like HST, actually provide tremendous opportunities for the individual researcher as both principal and co-investigators. Programs like Hubble represent "big science" while being developed, yet conversely typify "little science" during the operations and data analysis phases of the mission. Programs like Hubble also provide a tool to the community to train the next generation of space scientists.

NASA's FY 1991 budget provides for the on-going support of thousands of researchers and students to acquire and analyze data from previous missions. This year, we will also expand the research base with the initiation of 3 Life Sciences Specialized Centers of Research and Training, and the introduction of the multi-disciplinary Origins of Solar Systems Program.

The FY 1991 budget also provides for new flight opportunities in the near term for small missions. This year's small missions initiative, Earth Probes, responds to the critical need to address specific and highly focused problems in the Earth sciences discipline. The small missions occupy a special niche as critical elements of the Mission to Planet Earth initiative, and are highly symbiotic in their relationship to both EOS and other NASA Earth sciences satellites. Current Earth Probes missions include the Total Ozone Mapping Spectrometer (TOMS) instruments with potential flights in 1991, 1993, and 1995, to measure atmospheric ozone concentrations; and the NASA Scatterometer (NSCAT) to be launched in 1995 aboard the Japanese ADEOS to measure air-sea interactions, providing the data necessary to understand the role of oceans in controlling climate change.

Question 4: Constituents have expressed concern about the excessive lag time between the starting date of a NASA grant and the payment of money to the university. Whereas the National Science Foundation takes only several weeks to get the grant funds to a grantee university. NASA often takes six months or more to distribute grant monies. What is the reason for the delay in the disbursement of funds and what steps are being taken to correct this problem?

Answer 4: In FY 1989, the average processing time for a grant at NASA, following completion of the peer review and program approval process, was approximately one-and-a half to two months. This is an average figure. Specific grants may take more or less time depending on several factors including: the status of the grant as a new award or a renewal; grant size; availability of funding; the completeness of the university application and timeliness of the university application and timeliness of a university's response to requests for additional information.

Problems with NASA grant funding in recent years have been in the prompt initiation of those grants, not in the disbursement of funds.

Once initiated, fund distributions are prompt. The real problem has been one of renewing continuing grants on time and initiating new ones promptly. It has been a long-standing goal of the Office of Space Science and Applications to achieve on-time renewal of all grants. The events of the past two years have kept us from achieving this goal. In FY 1989, for example, knowledge of the Congressionally imposed $10 million reduction in planetary program support was gained so late in our planning process that all funding plans had to be revised. In fact, in order to accommodate the reduction with minimal impact on the grantees, performance periods of most grants were shortened so that they ended at the end of the fiscal year. The consequence of the last minute replanning and revision of budgets of grantees was that major delays occurred in initiation of almost all of the grants.

The effects of the grant anniversary change cascaded into FY 1990 when program plans again had to be modified at the last minute, to accommodate new budget reductions. In addition, a Congressional cap imposed on all research and development spending obligations until April 1, 1990, impacted our ability to fund grants in a timely manner. Monies available prior to April 1 were sufficient only to initiate a small percentage of the grants that were scheduled for renewal or initiation between October and April.

These delays were further exacerbated by the Continuing Resolution and associated interruption of OMB's apportionment of dollars to the agency pending determination of NASA's share of Gramm-Rudman taxes.

Steps have been taken every year to achieve on-time renewal. Typically, we are not able to achieve on-time renewals when external situations arise over which we have no control and for which alternatives are limited.

Question 5. Recently, a panel of the National Research Council (an independent scientific body) concluded that it was not in our national interest to undertake a joint unmanned robotic mission to Mars with the Soviet Union. What is NASA's position on the subject of joint robotic missions with the Soviets?

Answer 5: Exploration of Mars and the Moon, including robotic missions, is one of the goals of the President's Space Exploration Initiative. The U.S. will have an exploratory dialogue with Europe, Canada, Japan and the Soviet Union on possibilities for international cooperation in the Initiative. Guidelines for this dialogue are currently being developed by the National Space Council.

With respect to cooperation with the Soviets, we must acquire substantially more experience working with them before attempting a cooperative venture along the lines of a joint mission would depend on the capabilities of the Soviets could contribute and on whether the mission could be structured so as to protect U.S. technology and enable the U.S. to continue independently if necessary.

The U.S. does have several cooperative activities with the Soviets in the area of planetary exploration. The planned Soviet Mars 94 mission will be coordinated with the U.S. Mars Observer mission, and we will exchange scientists on these and the Magellan mission to Venus. The U.S. is planning to fly a French-built transponder on Mars Observer to relay data from a balloon experiment on the Soviet Mars 94 mission. Also, in accordance with a 1988 agreement to exchange the results of independent national studies, both sides have summarized the results of studies on Mars Rover Sample Return missions and Lunar Orbiters/Science Outposts. These activities will provide us with experience in working with the Soviets necessary to decide whether or not to move to more ambitious cooperation in unmanned or even future human exploration missions.

Senator **Gore**. Very good. As you know better than anyone, the Hubble Space Telescope has had its share of difficulties since it was released from the Shuttle cargo bay. Yet, as I said in my opening statement, millions of people, including members of this subcommittee, are eagerly awaiting the return of those first images. What is the current time frame for receiving them? You mentioned a few days to a week?

Dr. **Fisk**. The events that are going on at the moment, we have a test that is running today that we have two issues on the telescope we needed to work out. One, there was what appeared to be an alignment error between the fine guidance sensors and the fixed star trackers which turned out to be we added when we were supposed to subtract. That is easy to correct.

We have had a slight oscillation in the fine guidance sensors, and we have what we hope is a cure to that, which is being loaded today, and we will know tomorrow morning if that, in fact, takes care of that problem. If that is successful, we will then do what is called a focusing exercise on this. It is called—it has the name Bootstrap A.

Bootstrap A is to take the telescope and to bring it in focus of what is essentially three wavelengths. We think we are probably about 20 wavelengths down. We will focus it down to three wavelengths. If that is successful, we will take the picture. If that is not successful, then we will run it again until we get down to three wavelengths of light, the ultimate focus.

And it is important when people look at this picture they realize that the ultimate focus will be within a 20th of a wavelength of light inaccuracy, and so there is another continually focusing exercise that brings Hubble into its full capability. But we thought we would take a picture at the beginning of being three wavelengths of light within focus, and that should occur at the end of Bootstrap A which could be the middle or end of next week, depending upon many times we run the program.

Senator **Gore**. It could be what, now?

Dr. **Fisk**. Either in the middle or end of next week, depending upon whether we have to do Bootstrap A once or twice.

Senator **Gore**. How long will it take for NASA to then compare the images from Hubble to those received from ground installations to assure its accuracy?

Dr. **Fisk**. Essentially it occurs right away. The image we expect to take is of an object called NGC 3532. It is a star, an open star cluster not visible in the Northern Hemisphere, but visible from the Southern Hemisphere, and we have a ground based image right there which we are going to look at.

I only caution people that Hubble is going to get even better as we continue to bring the focus into its full capability.

Senator **Gore**. Now, it appears that one of the most serious problems may be the loss of the number two high gain antenna. How will this limit the flow of data from Hubble?

Dr. **Fisk**. Actually, we have not lost the high gain antenna. There is—the high gain antenna articulates and points at the TDRS satellite. And there is apparently a cable that as the high gain antenna gets over to—it can normally go, say, 90 degrees in this direction. If it gets over about 75 degrees, it runs into this cable, and so there is a narrow band, say, from 75 degrees to 90 degrees where that antenna cannot point.

But the whole rest of the space area deployed is fine. So it is only this narrow band that we are not able to point at. The impact will be negligible. It is simply a matter of not pointing the antenna at TDRS in that band, but pointing it, doing our data dumps to TDRS at other times during the passage.

I should also point out that we have had some good things that happen as far as that. We found that our fine guidance sensors work in what is called the South Atlantic Anomaly, which is a portion of the magnetosphere where there is a higher than average radiation. We did not think that would occur, but they seem to work there just fine, and that will actually increase the amount of observing that we can do beyond our original specifications. And that will more than compensate for any minor loss that would occur from this antenna having a region where we cannot point it.

Senator GORE. As I mentioned, the Hubble is the first of the four great observatories for space astrophysics. Hubble will be followed by the Gamma Ray Observatory, the Advanced X-ray Astrophysics Facility, and the Space Infrared Telescope Facility. Would you please discuss briefly the status of these other three projects, focusing on the types of measurements each will take, what we expect to learn from each, and how they are related.

Dr. FISK. The universe, of course, radiates all forms of electromagnetic radiation. What we can see on the ground is only visible light and radio waves and some very narrow regions of infrared. Everything else we have to be able to go into space to see. And if you want to observe objects in the universe and understand them, you have to look at all the kinds of radiation that comes out of them.

For example, take a quasar, one of the most enigmatic objects in the universe. It radiates maybe a million billion times that of an average galaxy and appears to be about the size of a solar system. It occurs near the edge of the observable universe and then presumably it is, therefore, a very young or early object, and we do not understand it.

If you try to observe quasars or understand quasars, you discover that they radiate. In infrared they radiate, in X-rays they radiate, in gamma rays they radiate in visible light, and each of those signals gives you some different piece of information about the physics of how a quasar works, and so the idea of the great observatories is to put four observatories that cover this electromagnetic spectrum and can give us total information about the objects in the universe.

Hubble is, of course, up. The Gamma Ray Observatory which was the great observatory for gamma rays goes in November. That is on schedule to go in November. AXAF was a new start in fiscal 1989, and it is scheduled for an early 1997 launch and SIRTF, the space infrared telescope facility is a new start to come that would be a new start to be launched at the end of the century.

These are long-lived observatories, and so the idea is to have them all up eventually at the same time. Many objects in the universe do not have short time scales associated with them. So that simply having them sort of contemporaneous in an astronomer's lifetime is probably sufficient overlap rather than having to worry that they are all up exactly at the same time.

Senator GORE. We have had some slippage this year in the launch dates for the shuttle. Could the cumulative slippage threaten the November date for the Gamma Ray Observatory launch?

Dr. FISK. The only threat that we have slipped in ASHTRO is going to slip two weeks approximately from the 17th or 18th of May to probably the 30th of May. We are in need of protecting the Ulysses launch window in October because that is a planetary launch, and that is a three-week window.

Senator GORE. So, that is the one that is in jeopardy?

Dr. FISK. It is not going to be in jeopardy, but in order to protect it we will have to look very hard at the SLS launch in August, and that can ricochet through the manifest in order to protect Ulysses.

Senator GORE. What part of August is that?

Dr. FISK. It is the 29th of August, and you can see there needs to be at least three weeks between launches just for turnaround time at the cape and Ulysses in early October.

Senator GORE. Now, once again, the total cost of the Hubble?

Dr. FISK. $1.544 billion.

Senator GORE. The Gamma Ray Observatory?

Dr. FISK. GRO was a development cost of $530 million, and that is again real year dollars. AXAF is just slightly over $1.6 billion. AXAF is a Hubble class instrument the space infrared telescope facility not being a new start, yet there is no definitive cost. It is about $1.5 billion.

Senator GORE. It is a Hubble class?

Dr. FISK. Yes.

If I may, we are giving you their real year dollar costs, so there is some allowance in there for inflation.

Senator GORE. I will keep that in mind. Your budget request, like the rest of the requests from NASA, got a fairly healthy increase in the President's fiscal year 1991 request. What additional 1991 activities were included in your budget to OMB and in your view, why were these programs deleted from your final budget submission?

Dr. FISK. The principal activity that we requested and were not successful at OMB is a project called SOFIA. It stands for Space—Stratospheric Observatory for Infrared Astronomy. NASA has had a very successful program of aircraft astronomy, and it is one of those programs which is very useful to universities because students fly on it, do their experiments and get quick results in order to complete their graduate theses.

It was not successfully funded. I think the way I would account for that is that the principal thrust of new activity in this budget was for global change research and Mission to Planet Earth and, given the limitations that exist in a budget which was growing already to over $15 billion, these additional activities were not possible.

Senator GORE. Last Tuesday at our hearing Dr. Donna Shalalla, Chancellor of the University of Wisconsin, mentioned that one of the key instruments aboard the Hubble, the high speed photometer was built by professors, graduate students and other undergraduates at her university. She told the subcommittee that over 100 students contributed to this project, and while this is a research program, it has an important side effect, working on the Hubble telescope educated and motivated these students in a way no lecture course could. I personally think this kind of linkage between research and engineering is critical, and I would like to see NASA encourage more of it.

What kinds of programs does NASA have to encourage that kind of linkage?

Dr. Fisk. NASA of course has—a large amount of its research is in fact done through universities. I will have to look at the number here, but I am guessing it is $200 million or $300 million a year, which is funded at universities for research, and it is across the entire spectrum of the program.

I mentioned in my opening remarks the small explorers, we call them SMEXs. One of them is done through the University of Maryland, the California Institute of Technology. There is another one done in the Boston area that includes participation from Harvard and MIT. And there is one through the University of California at Berkeley.

When we fly instruments on spacecraft frequently, if not always, almost entirely, there is university participation in that through principal investigators, through co-investigators. We fund basic research and analysis at universities to support sustaining grants that—for either theory or data analysis for laboratory work, for preparing instruments for future flights.

It would not be possible to conduct a space science program in the United States without the university community's active participation.

Senator Gore. I have some other questions on that particular subject that I will submit for your written answers, if you would do that.

I do want to cover some more ground here, and we have to move on. Suffice it to say that I would like to encourage NASA to consider, when awarding a contract for a particular instrument, to either a contract award to a university or to consider actively the educational benefits that can come from a particular applicant as opposed to another.

I would also like to encourage NASA to spend more time planning the educational part of its mission from its inception. You mentioned one lesson plan is going to be done, but that is relatively rare in the missions. It has happened before. There are others I understand, but I would like to see more thought given to building that into every mission more pervasively.

On our second panel, we will discuss the need for smaller, cheaper satellites as a means of stimulating the interest of great numbers of graduate students in engineering and science, producing more a cost-effective source of space-related research and encouraging entrepreneurial interests in space.

Are you satisfied with NASA's space science research program, is its focus on spacecraft small enough to accomplish these objectives and, in particular, in your view, do larger platforms hinder the involvement of graduate students and small science researchers?

Dr. Fisk. That is a complicated issue. I think what is always required is a balance between both large and small projects, and let me just share a couple of thoughts with you on this subject. We normally define small missions as small size, as the ones which involve a small group of researchers, frequently at a university, and have a quick turnaround time. That is in many cases a good definition.

You say, well, what is Hubble? Well, Hubble is obviously the epitome of big science because it took a long time to build and cost a lot of money, but when we go and use Hubble, it is all being used by small researchers, frequently the universities who will submit a proposal for observing time and hopefully have a quick turnaround time to get their observations. So it is big science when we built it and little science when we use it.

We are in need of making sure that there are an adequate number of programs in the system to train the next generation of scientists and engineers and particularly experimentalists. You cannot conduct big science unless you are also conducting little science in order to train the next generation.

That was our motivation for starting the SMEX program, the Small Explorer. That is our motivation for having Earth probes in addition to the early results that one can get with global change.

That is why we have a sounding rocket program and an aircraft program, all of which perform that function. Is there enough? Probably not.

Senator GORE. One of the obvious constraints in moving towards smaller satellites is the lack of an affordable technology for access to space. What is NASA doing to develop the advanced technologies capable of supporting smaller missions?

Dr. FISK. Of course, the access to space comes through the launch vehicles that are available to you. One of the reasons that we came forth with PEGSAT was to encourage companies like the Norvill Science Corporation in the development of the Pegasus launch vehicle, which I was very pleased to see was a successful launch because here was a technology for putting small satellites into space.

I have been very pleased in recent years by the number of small launch vehicle companies that are coming along, and I think that will make it possible for us to have small satellites launched on a frequent basis.

Now, as for the science on the satellites themselves, we can build them in any size that you want. I mean, that is not a constraint. The only constraint sometimes is on our appetite. The hardest part about building a small satellite is convincing the scientists involved to limit their expectations as to what the satellite will perform.

Senator GORE. You mentioned Pegasus. I went out and looked at that vehicle before it went up. David Thompson is going to be at next week's hearing on commercial space programs. It really is an exciting development for that team of young people. We will hear more about that next week I am sure.

Again, I have some other questions that we will submit in writing on that, but let me move to yet another subject, and that is computer networks, which our subcommittee has spent a lot of time on. Here we are dealing with problems related to the massive volumes of data expected to come from EOS.

I do think it is especially critical that we develop and effectively utilize high-speed fiber optic networks capable of transmitting data, in the multi-gigabyte range per second. Legislation reported earlier this year out of our full committee, slated soon for consideration on the floor calls for the creation of just such a network.

I will say for the record incidentally that I was very pleased that the Budget Committee in its formal action last week singled out the High Performance Computing Act as something specifically earmarked in the budget resolution. So that is a further indication that it really is going to happen this year.

The committee here was unanimous on it, but am I safe in assuming that as NASA tries to deal with these huge volumes of data in the Mission to Planet Earth Program and links different facilities around the country, such as your initial downlink station and your facilities for receiving, processing and storing data, that you will need a multi-gigabyte network?

Dr. FISK. That is correct.

Senator GORE. If you do not have one will that put a serious crimp in the Mission to Planet to Earth Program or would it just force a complete redesign of the data management?

Dr. FISK. No, I do not know that it would cause a complete redesign, but it would certainly interfere. Remember what the issue here is. We are in need of having a steady stream of data that is rapidly processed so that we do not get massive accumulation of it.

We are producing 10 terrabytes a day. It comes down to White Sands and it goes to Goddard and it is distributed to these remote active archive centers, and they are in turn required to turn this into usable products on time scales of 24 to 48 hours. And you need to be absolutely sure that you are not interfering with that process for taking the data from the satellite and turning it into usable products so that it does not accumulate on you.

And of course, the simplest part of this thing ought to be shipping the data around the country in order to—not that—that that should not be a delay in your process.

Senator GORE. Of course I am always anxious to stir up a lot of new business for Federal Express in Memphis.

You could replicate it all on magnetic tape, I guess, and ship it around, but it would be more efficient.

Dr. FISK. It is true that as you begin to distribute to actual individual users at the universities, you have to assess whether they in turn need it in real-time or whether or not optical disks, sent through the mail, even with the U.S. Postal Service is able to do that.

Senator GORE. For the record, I want you to answer questions on what you are now doing to assist in the development of this network technology, which will be so critical to the success of the Mission to Planet Earth, and what you are doing about the needed advances in data storage technology. I do not think we are moving ahead quickly enough in that area either.

Now while we are on the subject of data management, I made reference to the GAO report, which was so harshly critical of NASA's data management practices. I know NASA has taken steps to address the GAO report. I also know that a lot of people have asked that NASA start implementing the recommendations.

What is being done with regard to the recommendations in data management and archiving? Is NASA moving to comply with GAO's recommendations?

Dr. FISK. The answer is yes, but I hasten to add here that in our judgment we were already doing the many things that were suggested in the report.

The report of course, as you know, attacked us on the grounds that we were not adequately safeguarding the data. Their versions was that our tapes were at risk, and as we pointed out frequently there is no evidence either cited in the report or that we are aware of that we ever lost a significant amount of science data.

The recommendations are good ones. They are ones we concur with. They are ones that in many cases, if not all, we have had under way and are doing our best to proceed with.

Senator GORE. What plans do you have for an EOSDIS, the information management part of the Earth Observing System program, to properly protect the massive amounts of earth science data that will be collected from EOS?

Dr. FISK. There are many things. As you know, this is of course our highest priority area in EOS, and we are putting a substantial fraction, more than half of the funding of the EOS program, into the data and information system and related science.

In the fiscal year 1991 budget there is a facility request for a building to be built at the Goddard Space Flight Center which will be a state-of-the-art building for handling and storing data and a computer facilities associated with it. Ad so we are not going to leave to chance that the physical environment in which the data will be handled will not be very adequate to do the job.

We also—of course, the data will be archived in various ways. We will make sure that there is always a set of complete data available because you never know when you want to go back and look at the things from the past that might have information you did not realize the first time.

So there will be an adequate archive of the total data set somewhere in the country.

Senator GORE. We have some other questions for the record on nuclear reactors and space science observations—and I know you have given a lot of thought to that—and other related questions.

I know that you have a meeting you need to go to later today and we have other witnesses that we need to get to in order to finish up expeditiously. I have consulted with other Senators, and we will hold the record open for questions in writing from other subcommittee members. With that, let me thank you again, Dr. Fisk, for coming back and testifying again. We are always glad to see you and look forward to working with you and your colleagues throughout the coming budget year.

Dr. FISK. Thank you very much.

Senator GORE. Thank you.

I would like to call our panel of witnesses now. Dr. John Dutton, Dean of the College of Earth and Mineral Science at Pennsylvania State University, and he appears representing the Space Studies Board of the National Academy of Sciences; Dr. Glenn Mason, Associate Professor of Physics at the University of Maryland, who appears representing the Space Science Working Group of the Association of American Universities based here in Washington; and Dr. Paul Coleman, Jr., the Director of the Institute of Geophysics and Planetary Physics at the University of California in Los Angeles.

Gentlemen, we are delighted to have all three of you present here today, and we earlier got consent to place your prepared statements in full in the record. If you can proceed with a summary of your remarks, we would appreciate that.

STATEMENT OF JOHN A. DUTTON, DEAN, COLLEGE OF EARTH AND MINERAL SCIENCE, PENNSYLVANIA STATE UNIVERSITY, ON BEHALF OF THE SPACE STUDIES BOARD, NATIONAL ACADEMY OF SCIENCES

Dr. Dutton. Thank you very much, Mr. Chairman. Thank you for inviting the Space Studies Board to testify on the vitality of the civil space research effort. The Chairman of the Board, Dr. Louis Lanzerotti, regrets that a previous commitment prevents him from appearing here today, but I am presenting these remarks on his behalf.

As a member of the space research community I cannot emphasize strongly enough how excited we all are today to be participating in one of the most exciting eras in the history of the United States space program.

We have recently launched a number of long-awaited science missions, COBE, Magellan, Galileo and the Hubble Space Telescope. Between now and the mid-1990s we will launch another 30 space research missions. Analyzing the wealth of data that will be generated from these missions will excite and stimulate the research community for many years. We anticipate significant progress in science and in applications.

Today we would characterize the space research program as both vibrant and robust. However, just as there are essential minimum requirements for maintaining human health and fitness, so too are there critical requirements for maintaining a vital space research program.

I would like to summarize those requirements. The first is a sound scientific foundation that takes account of the guidance and views of a broad group of knowledgeable people. In constructing its scientific program, NASA has gone a good job of soliciting and using the advice of the scientific and engineering communities.

We are particularly pleased that NASA has taken advantage of the decade-old research strategies that Space Studies Board has developed for each of the major science and applications disciplines. In fact, virtually every science and applications mission that has been launched recently or is currently manifested has its roots in one of the Board's discipline strategies. The present system works well.

In managing its scientific program, NASA recognizes that the continued integrity of its scientific endeavor depends on adequate peer review. We know that there will be instances when the Nation may choose to support large-scale projects in science or engineering for reasons other than scientific. However, we emphasize that there are risks in doing so, risks to science and risks to our continued success in science.

The second essential requirement is an adequate infrastructure involving many components in the public and private sectors. One of those components is the grants made through the research and analysis program to individual investigators in universities and laboratories all over the United States. The research base supported by these grants is as integral to the vitality of the space research program as is any spacecraft, computer or any facility. It is the foundation for progress in space research.

Because of economic realities, NASA has often been forced to choose between growth or maintenance of its research and analysis program and the seemingly more urgent requirements of missions in space flight.

The planetary and microgravity research programs have been particularly impacted in recent years. As the many science and applications missions presently manifested move through the queue, there is a danger that the other disciplines will be similarly affected: astronomy, life sciences, earth sciences, solar and space physics. This is one of the areas in which we believe some new approaches and policies are needed.

A third essential requirement is the provision of adequate space flight opportunities on a timely basis. It is imperative that we carefully assess the best, most economical and most effective way to get science payloads into space and to maximize scientific return.

We must match the launch capability to the scientific requirement, we must provide opportunity for science to move ahead and we must shorten the time between the formulation of a mission concept and the launch of a spacecraft.

The Board has issued a number of reports on the use of Explorer spacecraft. The well-defined nature of this class of mission provides maximum flexibility to both NASA and to the investigators and allows for rapid progress from initiation to completion of the mission.

The fourth essential requirement is flexibility, flexibility to deal with unforeseen circumstances, flexibility to accommodate a variety of opportunities and flexibility to encompass important large initiatives. This year, in addition to its ongoing programs, NASA has a large role to play in two Presidential initiatives, the U.S. Global Change Research Program and the Human Exploration Initiative, now called the Space Exploration Initiative.

The fiscal year 1991 budget proposal in the NASA Office of Space Science and Applications incorporates these two initiatives in what appears to be a responsible and realistic way.

An Academy report issued in 1988 anticipated this situation, recommending that a distinction be maintained between a base program and special initiatives agreed upon by the President and the Congress. We trust that this important distinction will be kept in mind as the Congress and the President complete their budget deliberations.

The Space Studies Board is carefully considering these two Presidential initiatives. The Board has created a committee on human exploration, chaired by Board member Noel Hinners. This committee will examine important questions concerning the science prerequisites and the science opportunities of prolonged human space flight. We hope to complete the study within a year, and we will be pleased to discuss it with the committee at that time.

The Board's committee on Earth studies is now concluding a detailed assessment of NASA's plans for the Earth Observing System, including the flight configuration, the EOS data and information system and the program management structure. The EOS initiative addresses important objectives and is the largest science and applications program ever undertaken by the U.S. civil space program. The Board and its committee are working hard to be confident that plans for EOS are adequate to ensure success. We hope to complete our review this month and we will be pleased to discuss our conclusions with the Subcommittee once we have published that report.

The fifth essential requirement is responsiveness in meeting the needs of the scientific community and the Nation. We feel that NASA has been responsive to the scientific community with the strategic plan prepared by the Office of Space Science and Applications. This plan is based directly on recommendations made in the Science Strategies and Space Studies Board.

However, a less successful example of responsiveness to the scientific community is the proposed space station. Despite a multitude of recommendations from advisory committees, current plans for Space Station Freedom suggest that it may not be of optimum use to the two scientific communities that are depending upon it: life sciences and microgravity sciences.

With life sciences this is critical. Because, today we do not have the knowledge necessary to ensure the productivity and well-being of humans in space for long periods of time, as would be required for a mission to Mars.

The Board's committee on space biology and medicine published a report in 1987 setting forth a strategy for the 1990s. It recommended that (1) a dedicated life sciences laboratory be provided on the space station and (2) that space biology and space medicine research be conducted as focused missions on the station. Neither of these recommendations is implemented in the currently planned space station.

The Board also recommended that a variable force centrifuge be provided on the space station. While the centrifuge continues to be discussed and debated both within NASA and the Congress, its size, placement and ultimate availability remains uncertain.

Thus, is it my responsibility to advise the Subcommittee of our continuing concern about the utility of the space station as it is now planned for microgravity research and for the life sciences research necessary to support long duration human space flight.

The sixth essential requirement is a program that is balanced across disciplines. Clearly, it is a difficult challenge to maintain a balanced and vital space research program in the face of political and economic realities.

Senator GORE. Excuse me, Dr. Dutton, we are going to have to go for a vote. I was thinking that you were just about finished.

Dr. DUTTON. I am within about three paragraphs, Mr. Chairman. Would you like me to finish?

Senator GORE. Yes, or else if you need more time we can come back.

Dr. DUTTON. I do not have that much to go.

The Space Studies Board is addressing this issue with a study on setting priorities in space research. We hope that as a result of the study we can actually make priority recommendations across the initiatives of the space science and applications disciplines.

This will not be easy but we expect to be successful and I will be pleased to share our conclusions with the Subcommittee at some point in the not too distant future.

The seventh and last on my list of essential requirements for a vital space research program is continuity in funding and management. The need for continuity permeates every aspect of the program, lack of continuity can have any number of deleterious effects. This is an area where Congress, NASA and the research community should work together to develop innovative approaches and policies.

NASA and the research community must be willing to propose realistic funding requirements and set realistic schedules. Congress and the administration must provide the leadership and commitment necessary for the program to proceed in a predictable manner.

This concludes my remarks I believe that on the whole the Nation's space research program is reasonably fit. The improvements that are needed are all possible to achieve. It is important to remember that today's successes in space research are the fruit of goals and plans developed over the past 10 or 20 years. The continued vitality of our space research program will depend upon making the wise investments today that will ensure tomorrow's successes.

[The statement and questions and answers follow:]

TESTIMONY

JOHN A. DUTTON
DEAN, COLLEGE OF EARTH AND MINERAL SCIENCE
PENNSYLVANIA STATE UNIVERSITY

for

SPACE STUDIES BOARD
NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCE

Thank you for inviting the Space Studies Board to testify regarding our views on the health of the nation's civil space research effort. Louis J. Lanzerotti, Chairman of the Space Studies Board regrets that a previous commitment prevents him from appearing before you. These remarks are presented in his behalf.

The Space Studies Board was established in 1958 by the National Academy of Sciences to serve as the focus of the institution's interests and responsibilities in space research and to advise NASA, other agencies concerned with civil space research and the nation on the elements and requirements for a vital space research program. The Space Studies Board has a well established record that is firmly based in a consensus resulting from debate and discussions between representative scientists from the research community over a thirty-year period. Much of the Board's work is carried out through its standing committees that represent each of the major space science and applications disciplines -- astronomy and astrophysics, space biology and medicine, microgravity research, solar and space physics, earth studies and planetary and lunar exploration.

The purview and responsibilities of the Board have evolved over time, corresponding with the needs and maturing of the nation's civil space program. As recently as 1988, the Board underwent a major reorganization that resulted in a broadening of its advisory purview, both in terms of research areas and of federal agencies other than NASA. Last year when the Space Studies Board testified before this Committee, we described in detail the rationale behind this reorganization and some of the tasks that we would undertake. I will give you an update on our progress in the context of some of the issues discussed below.

The Subcommittee has asked me to comment on several related topics: (1) The general health of space science and applications today, (2) What NASA is doing "right" and, conversely (3) What, in the opinion of the Board, NASA and the nation could do to improve its civil space research program.

As a member of the space research community, I cannot emphasize enough our enormous excitement and sense of anticipation we are experiencing in what has been referred to as "one of the most exciting eras in the history of the United States space program." We have recently witnessed the successful launch of a number of long-awaited science missions -- COBE, Magellan, Galileo and the Hubble Space Telescope. Between now and the mid-1990's, over thirty science and applications missions will be launched. Analyzing the enormous amount of data that will be generated from this wealth of missions promises to excite the research community for years to come.

How is the overall health of space science and applications? At this moment in time it would have to be characterized as both vibrant and robust. However -- at the risk of exaggerating an analogy -- just as there are essential minimum requirements for maintaining human health and fitness, so too are there crucial requirements for maintaining a sound space research program. I would like to relate to you today those characteristics we believe to be the essentials of a continuing vital space program. You might call them the "Minimum Daily

Requirements" for space research. In so doing, I will address the second and third part of your request, describing those areas where there is evidence of success and those areas where we believe improvement may be indicated.

REQUIREMENTS FOR A "HEALTHY" SPACE RESEARCH PROGRAM

I. Scientific Basis

The civil space research program must be based on a sound scientific foundation. This foundation should include guidance and input from the widest sampling and most knowledgeable sources available. Over the years, NASA has done a particularly good job soliciting and using advice from the science and engineering communities. The Agency has numerous internal and external advisory committees, each tasked with a unique advisory responsibility. We believe this is a system that works.

Research Strategies

In addition to serving as the major external advisory group that advises NASA on space science and applications, the Space Studies Board has, over the past fifteen years or so, provided what we call research "strategies." With one exception (microgravity research) the Board has developed a research strategy for each of the major space science and applications disciplines. These strategies address an approximately ten-year period and describe a baseline level-of-effort. They identify the major scientific questions and goals for each field and make recommendations as to how to address them. They are not mission strategies but rather are the basis from which the Agency plans missions.

NASA has been extremely responsive in employing the scientific goals and recommendations put forth in the Board's strategies. In fact, virtually every science and applications mission that is currently manifested or recently launched has its roots in one of the discipline strategies that was produced by the Board. I say this not to heap praise on the

Space Studies Board, but to emphasize that the strength of a science and applications program is directly dependent on fundamental and well articulated goals and objectives.

Space Studies Board Discipline Assessments

One of the new activities that derived from the Space Studies Board's reorganization has been for each of the Board's discipline committees to undertake an assessment of NASA's (and other agencies, where relevant) progress in implementing the research recommendations made in its published reports. When this activity is completed, it will give us a comprehensive picture of not only the "health" of space research today, but a description of what remains to be done. We would be happy to brief the Subcommittee on this activity when it is completed.

Peer Review

One of the cornerstones of this country's scientific accomplishments is the well respected process of peer review. Through peer review, the scientific community evaluates proposed research, subjecting it to the highest standards. We believe that the continued integrity of our scientific endeavor depends directly on this process. Obviously, there will be instances when the nation chooses to support large scale projects or programs in science or engineering for reasons other than scientific ones. However, knowing this to be true, we emphasize that there are risks, risks to science and risks to our continued success.

II. Infrastructure

This is a fashionable term of late that describes the supporting elements of something ... be it public works like highways and bridges or the underpinnings necessary to solve the crisis in science and mathematics education. One of the basic elements of the space research infrastructure are the grants made to individual investigators in universities and laboratories all over the United States. These grants -- a budget line-item called "Research and Analysis" (R&A) -- support a wide range of research, from the most basic theory to the detailed analysis of data derived from space missions like Magellan, Viking, or the Upper Atmospheric Research

Satellite. The work done by these investigators cannot be done by NASA or another federal agency. That is neither feasible nor desirable. It is, however, as integral to the health of the space research program as any spacecraft, any computer, or any facility and must be considered in that light.

In recent years, largely because of budget cutbacks and economic realities, NASA has been forced to choose between growth or maintenance of support in Research and Analysis funding, versus continued hardware development or other spaceflight, schedule driven choices. Particularly impacted in recent years have been the planetary and microgravity research programs. But, because there is a direct correlation between Research and Analysis cutbacks and funding requirements associated with spaceflight, as the many science and applications manifested missions move up in the queue, all the space research disciplines will be similarly affected -- astronomy, life sciences, earth science and solar and space physics.

This is one of the areas where we believe some solutions are needed. If the space research program is to continue to thrive, particularly over the next several years as we continue to launch and extract the scientific return from the numerous missions that are planned, a way must be found to ensure that the supporting infrastructure ... the individual investigator ... is intact.

III. Opportunity

Without opportunities to fly there is, of course, no space research program. It is not news that space research is complicated and expensive, both in terms of time and money. We congratulate NASA for resuming its mixed fleet policy following the Challenger accident. It is imperative that we objectively assess the best, cheapest, most efficient ways to get payloads into space and maximize scientific return. Sometimes it may be on the space shuttle. Sometimes it may be on sounding rockets. Sometimes it may be on an Explorer. And sometimes, it may be by cooperating with another country. The important thing is to exploit every possible spaceflight opportunity with the appropriate launch capability.

The Board has issued a number of reports on the use of Explorers. [*A Strategy for the Explorer Program for Solar and Space Physics (NAP, 1984). The Explorer Program for Astronomy and Astrophysics* (NAP, 1986) and *Strategy for Earth Explorers in Global Earth Sciences* (NAP, 1988). Through these reports, the Board has described how Explorers can provide a flexible level-of-effort program in a number of space research disciplines. The well defined nature of this class of mission provides maximum flexibility both to NASA and the investigator and allows for rapid progress from initiation to completion.

IV. Flexibility

Another attribute of a vital space research program is flexibility, both in terms of dealing with unforseen circumstances or opportunities as well as how it is affected by the imposition of large new initiatives. For example, this year, in addition to its ongoing program, NASA has a very large part in two Presidential proposals -- the Global Change Research Program and the Human Exploration (now called Space Exploration) Initiative.

In it's report to incoming President Bush, *Toward a New Era in Space -- Realigning Policies to New Realities (NAP, 1988)*, the National Academy of Sciences/National Academy of Engineering addressed this issue.

> "A civil space program capable of achieving national goals should have two distinct components. The first should be a balanced, stable **base** program to ensure ongoing U.S. competence in fundamental space activities .... Stable funding for this base, or core, effort should be assured before any additional large-scale leadership initiative is undertaken.
>
> The second component of the civil space program should consist of large-scale **special initiatives** that the President and the

> Congress decide are in the national interest and for which they seek public support. This component, which would depend heavily on a stable base program, is motivated primarily by political, cultural, and international considerations, although it also may serve scientific purposes.... Clearly, such initiatives should not be undertaken without the commitment to fund and support them adequately over the period necessary for their accomplishment."

The Space Studies Board agrees fully with this position. At this point, there is no evidence to suggest that NASA's core space research program is not sufficiently flexible to accommodate the President's proposals. In fact, the Office of Space Science and Application's FY 1991 Budget Proposal -- which is based on their Strategic Plan -- incorporates these two initiatives in what appears to be a realistic way. We have some confidence, that as the Congress and the President complete their budget deliberations and negotiations, that the principles put forth in the NAS/NAE 1988 report will be kept in mind and the integrity of the ongoing program will be maintained.

Space Exploration Initiative

As you know, the National Research Council recently issued a report, *Human Exploration of Space -- A Review of NASA's 90-Day Study and Alternatives (NAP, 1990)*, in response to a request from the National Space Council. This report specifically addressed the Council's request for a review of NASA's 90-Study as well as some alternative approaches and various technology issues.

One of the new Space Studies Board study activities that I mentioned in my testimony to you last year is the creation of a Committee on Human Exploration chaired by SSB Member Noel Hinners. This study is concerned with the scientific and technological research that could help to provide the foundation for a human exploration program. It is of a much broader nature than that conducted in response to the Space Council's request. Specifically, the study will address the following sorts of questions. "What scientific knowledge must be obtained as a prerequisite for deciding to undertake prolonged human space missions? What scientific opportunities might specifically derive from prolonged human space missions? What are the diverse options for prolonged human space missions?" The SSB's discipline committees will have a large role in advising the Hinners Committee and the Board on specific space science and applications questions, issues, and requirements. We hope to complete this study within a year and would be pleased to discuss it with the Subcommittee at that time.

Mission to Planet Earth

As you know, two major space-based components of the President's Global Change Research Program and NASA's Mission to Planet Earth are the Earth Observing System (EOS) and Earth Probes. The Space Studies Board has several published reports that concern the science that will be accomplished by these two missions: *A Strategy for Earth Science from Space in the 1980's -- Part I: Solid Earth and Oceans* (NAP, 1982), *A Strategy for Earth Science from Space in the 1980's and 1990's -- Part II: Atmosphere and Interactions with the Solid Earth, Oceans, and Biota* (NAP, 1985) and *Strategy for Earth Explorers in Global Earth Sciences* (NAP, 1988). The latter report includes the Board's position and recommendations on the scientific need for an Earth Probes line. We believe that NASA's FY 1991 Budget proposal begins to implement with these recommendations.

Last June, the Space Studies Board asked its Committee on Earth Studies (CES) to assess NASA's plans for the Earth Observing System, including the EOS Data and Information System. EOS is the largest science and applications project ever undertaken by the U.S. Civil Space Program. The magnitude of the project is enormous. The CES assessment, while not requested by NASA, is fully consistent with the Board's past practice to provide an independent analysis of every major new start. It includes such critical issues as the management plan that will guide the project through 15 years, the system concept to handle the phenomenal flow of data, and the planned flight configuration. The Board has been reviewing the Committee's progress on this assessment over the past year and expects to review the final draft at its May meeting. We anticipate that we will be able to forward this report to NASA later this summer to assist the Agency in planning for this important but complex program. We would be happy to brief the Subcommittee on this issue at that time as well.

As you may know, there is another parallel effort going on at the NRC that concerns the entire Global Change Research Program and the EOS mission in that context. This is in response to a request from Dr. Allan Bromley, the President's Science Advisor. It is expected to be completed no later than July 1 of this year.

New Technologies and Emerging Disciplines

Another critical feature of flexibility is how it accommodates emerging science and new technologies. It is essential that NASA and other government agencies incorporate the views of the user community in the process of developing technology for future space science and applications missions. Another of the new SSB activities is the creation of a Committee on Technology Developments. This Committee, comprised of members from both the NRC's Space Studies Board and Aeronautics and Space Engineering Board (ASEB), will collaborate to provide advice to ensure that appropriate technologies are identified to meet scientific goals and that they are developed in a timely manner. The Committee, still in a stage of definition, will hold its first meeting May 8, 1990.

Some fields of space research are more mature than others. Space astronomy has existed since the very beginning of NASA while areas such as life sciences and so called "microgravity science" are at a far earlier stage of development. As I mentioned before, the Space Studies Board has published research strategies for every major space science and applications discipline with one exception, microgravity. This very diverse field includes three major elements: (1) fundamental physics and chemistry, (2) fluids and materials science and, (3) biotechnology. These elements span the continuum from fundamental science, through applied science and technology, to focused investigations having commercial significance. The SSB recently formed a standing discipline committee on microgravity research chaired by Robert Sekerka, Dean of the Mellon College of Science at Carnegie Mellon University. The near-term charge to the Committee is to ascertain whether the field is of sufficient maturity to warrant a traditional research strategy and, if it is, to produce such a strategy. A critical indicator of NASA's flexibility will be how responsive it can be to implementing the recommendations necessary to establish this relatively new and emerging field of space research.

V. Responsiveness

OSSA Strategic Plan

Another measurement of vitality in the space research program is how responsive it is to those it serves -- the users and the nation at large. This characteristic is closely linked with the ideas and concepts discussed under "flexibility" above but is of a slightly different nature. NASA has been, for example, extremely responsive to the user community with its Office of Space Science and Applications Strategic Plans over the past several years. This Plan is based directly on the recommendations made in the Board's science strategies. Using the strategies as a guide, NASA conducts an annual process that involves a review of the needs of the Agency and input from both internal and external advisory groups. It provides a basis for near-term decisions and the planning of future efforts. We believe the OSSA Strategic Planning process represents an excellent example of a responsive partnership between NASA and the space research community.

Space Station Planning

A less successful example of responsiveness to the user community is the proposed space station. There have been a multitude of recommendations from advisory committees that were created to advise on the scientific requirements for the station. However, current proposals for Space Station Freedom suggest that it may not be of optimum use to the two primary communities for which it is intended -- the life sciences and the microgravity sciences. The Board and several of its committees have had an ongoing dialogue with NASA about the space station since it inception. We will continue to do so as it evolves and is eventually deployed. One issue that has been the subject of ongoing discussion is the compatibility of life sciences and microgravity research. Is it feasible to conduct research in these two fundamentally different disciplines on the space station that is planned?

The Board's Committee on Space Biology and Medicine published a report in 1987, *A Strategy for Space Biology and Medical Science for the 1980's and 1990's*, (NAP, 1987). This report is long-range research strategy for fundamental biology, human behavior, and human physiology. Two pivotal aspects of this strategy are recommendations that there be a dedicated Life Sciences Laboratory on space station and that space biology and medicine research be conducted as focused missions on the station.

> **Dedicated Life Sciences Laboratory** -- "Based on the dual requirements of continuous access and manned intervention, the committee recommends that there be a dedicated Life Sciences Laboratory (LSL) on the Space Station."
>
> **Focused Missions** -- "It is recommended that the space biology and medicine research time on Space Station be divided into 3- to 6-month blocks, with each block largely devoted to a single research area. Missions in each subdiscipline should occur at least three times each decade."

In making these recommendations, the Committee and the Board concluded that they are critical to the successful implementation of the rationale on which the research strategy is based. The dedicated Life Sciences Laboratory is required because of the unique requirements of life sciences research: continuous access, manned intervention, the collection of large amounts of data and the gradual improvement of research protocols. Focused missions are recommended in order to gain the most information in the most efficient way possible. Flexibility and innovation are both critical in biological experimentation. There is a greater chance that the results obtained will have a major impact on the discipline involved.

This is especially true if all the experiments flown during the 3- to 6-month mission are focused on the few essential questions in each research area that need to be answered in the next 10 to 20 years. If this approach is adopted, space biology and medicine can become a mature science within one or two decades and those critical questions that must precede a program in human exploration may be answered. Neither of these recommendations is incorporated in the currently planned space station.

At this point in time, we do not have the evidence necessary to guarantee the productivity and well-being and humans in space for long periods of time -- as would be required in a mission to Mars. A third pivotal aspect of the CSBM strategy concerns the requirement for a variable force centrifuge on the space station. While the centrifuge continues to be discussed and debated both within Congress and NASA, its size, placement, and ultimate availability remain uncertain.

> "The committee still recommends that a variable force centrifuge of the largest possible dimensions be designed, built, and included in the initial operating configuration of the Life Sciences Laboratory. A VFC is an essential instrument for the use of space biology and medicine. [It] is the single most important facility in any life sciences program."

Thus, in the context of "responsiveness" I feel it is my responsibility to advise the Subcommittee of our continuing concern about the utility of the station if it proceeds as currently planned. This is a multi-billion dollar research effort that must incorporate the requirements of the research it is meant to facilitate, particularly as we move forward to research prerequisites for the human exploration program.

VI. Balance

A sound space research program is one that is balanced within and across disciplines. The earlier mentioned NAS/NAE report, *Toward a New Era in Space -- Realigning Policies to New Realities*, discusses balance:

> "A challenging space science program should be pursued both as an instrument of U.S. leadership and for the intrinsic knowledge that can be gained. Scientific objectives addressing outstanding, fundamental questions must be the dominant factors in defining the space science program and in determining the characteristics of individual missions such as spacecraft, launch vehicles, and instrumentation.
>
> A base program in space science would be designed to increase understanding of astrophysical phenomena and the origin and evolution of the universe; the Earth and the solar-terrestrial environment; the origin and evolution of the Solar System; fundamental physical, chemical and biological processes; the effects of the space environment on living beings, and the factors governing the origin and spread of life in the universe. Assured, predictable, and frequent access to space is critical to an effective base program. There should be a spectrum of flight opportunities, with major facilities such as the Hubble Space Telescope balanced with increased opportunities on Explorer-class missions and continued availability of low-cost opportunities using aircraft, balloons, rockets, and shuttle-carried experiments.
>
> There also must be a strong program of research and data analysis that sustains intellectual vigor both through the development of the scientific and technical basis for future missions and through detailed study of results from current and past missions."

Priorities in Space Research

One of the many challenges of maintaining a balanced space research program is doing so in the context of political and economic realities. Another of the Space Studies Board's new activities is a study on setting priorities in space research. The study began last summer with a workshop on this topic. Because of its very nature, that workshop involved participants with highly diverse backgrounds -- Congress, the Office of Management and Budget, technical support organizations such as the Congressional Research Service and Office of Technology Assessment, and the fields of philosophy, economics, finance, and space research. The present Task Group's membership, though considerably smaller in number, represents a microcosm of that diversity. The first phase of the study which will document the role of space research and establish a rationale for setting priorities, will be completed by mid-summer. The second phase will develop a methodology for setting priorities in space research. The obvious and hoped for final product will be to actually make priority recommendations across all the disciplines of space science and applications. It is a gross understatement to say that this will be a challenge. However, with every optimism that we will be successful, I would welcome the opportunity to share our conclusions with the Subcommittee at some point in the not too distant future.

VII. Continuity

The last component on my list of essentials is continuity. A stable space research program requires continuity, in funding and in management. The need for continuity permeates every facet of the program, from grants to individual investigators to design and development of hardware. Lack of continuity (as well as opportunity) can have any number of deleterious effects on the space program. Individual investigators need some stability in their funding in order to support ongoing work in the laboratories and to entice bright young investigators into the field. Program managers need some assurance that the funding requested or approved for a given project will in fact be available on a year-to-year, timely basis.

This is an area where Congress, NASA, and the research community need to work together to develop some innovative solutions. NASA must be willing to propose realistic funding and schedule requirements for what it wishes to undertake. The research community must do the same. And, Congress and the Administration must provide the requisite leadership and commitment necessary to realize these undertakings. A well managed, well conceived project cannot be expected to sustain year-to-year shortfalls and still produce promised results.

This concludes my remarks. I've tried to provide you with our ideas of the most fundamental and essential elements of a "healthy" space research program -- a strong scientific base, a well founded infrastructure, opportunity, flexibility, responsiveness to the research community and the nation's needs, balance across and within disciplines and continuity of funding and management. I believe that on the whole, the nation's space research program is fit. Where improvements are indicated, they are improvements that are possible. It is important to remember that the science and applications missions that will be launched over the next five years are the fruit of plans and goals from the past fifteen to twenty years. Continued health of the program will depend on what we today are willing to invest in the future of tomorrow.

NATIONAL RESEARCH COUNCIL
COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND APPLICATIONS
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July 11, 1990

Senator Al Gore
Chairman
Subcommittee on Science, Technology
and Space
427 Hart Senate Office Building
Washington, D.C. 20510

Dear Senator Gore

Both Lou Lanzerotti, Chairman of the Space Studies Board, and I want to thank you again for asking us to testify before your Subcommittee last month. I am pleased to answer your additional questions.

Future of Space Sciences

Today, the NASA space research programs are generally healthy and more vital than in recent years. There are, however, exceptions. Continuing restrictions of the support of Research and Analysis has serious implications for the space research community. Some way must be found to provide ongoing, more stable support for these activities. A second exception is the lack of sufficient focus and priority for a life sciences program that can provide the knowledge necessary to plan extended human missions in space with some confidence.

The OSSA Strategic Plan has proved to be very effective in providing strategic and programmatic guidance for space research missions in the near term. Neither the Agency nor the scientific community has yet addressed the issue of selecting, ordering, or prioritizing the many opportunities presented in the *Space Science in the Twenty-First Century* report. It seems to some of us that a formal process is needed to develop a scientific community consensus on priority recommendations that adequately address the scientific opportunities and political realities. The Task Group on Priorities in Space Research of the Space Studies Board is currently formulating the rationale for such a process and hopes to move soon to developing a specific procedure for organizing the many opportunities into an agenda from space research. We believe that we are creating an exciting new vision for U.S. space research and look forward to discussing our conclusions with you when we have completed our deliberations.

The primary focus of NASA at present is on human space flight... as evidenced by planning for the space station and, the President's Space Exploration Initiative---and on the Earth Observing System. Human space flight, (the Space Station and the Space Exploration Initiative) are not now driven by scientific objectives or the needs of the scientific community. It is conceivable that these efforts could be modified to have some congruence with scientific opportunities.

The Earth Observing System is believed by the earth sciences community to be essential to developing the improved understanding of the Earth System necessary to confidently assess the implications of global change from natural causes and from human activities. EOS is a NASA activity with high priority that is driven by scientific requirements and the objectives of the earth sciences research community. Because of the scope, cost, and duration of EOS, there is considerable ferment over programmatic issues, including configuration of spacecraft, the design of the data and information system, and the flexibility to adapt to scientific advances that will occur during the lifetime of the mission.

Over the years, the Agency has supported space science and applications with sufficient resolve that there have been some great accomplishments. Today, the space research program is reasonably healthy. As we move to the future, both the Agency and the research community need to work together to ensure that the finite resources which will be available are used effectively.

Funding Priorities

In view of economic and political realities, I would not argue that space research should receive a greater fraction of the NASA budget than is now being requested. The scientific community would be strengthened by more emphasis within OSSA on smaller, more focused missions and more emphasis on Research and Analysis activities. The OSSA program is important to the nation's universities and the entire nation because it is the foundation for improved understanding of the universe, solar system, and the Earth itself and for applications of that knowledge to a wide variety of human activities. Without the R&A program, space research and applications could wither rapidly; without new missions and new information from space, space research could become theoretical and introspective and would soon lose its luster as one of the most exciting human pursuits.

Education

This nation needs to interest young citizens in science and engineering in the elementary schools, high schools, and colleges and universities. This is important both for educating future scientists and engineers as well as, and perhaps just as importantly, for encouraging a "technically literate" citizenry.

In the elementary and high schools, the pupils could be shown that science is exciting and challenging by providing them with data, information and examples from space research. Teachers could be given classroom materials specifically designed to take advantage of the results of space research; they could be brought together in workshops to formulate new approaches using information from space research. NASA and the space industries could recruit university students to science and engineering with attractive scholarship and opportunities for co-op programs. Graduate students cannot be attracted to space research without adequate financial support and the prospect of rewarding careers---stable R&A funding and a greatly enhanced NASA Graduate Fellowship is necessary for a strong national civil space program. A greater emphasis on smaller, more focused missions could provide university students at all levels with more opportunity to participate directly in the development and operation of spacecraft, the analysis of data and the formulation of exciting scientific results.

Estimates of the shortage, or even possibly the oversupply, of technically trained talent required by the country in the next decade or more are fraught with large uncertainties. In the space disciplines, as well as in their technical fields, more attention needs to be given to achieving a more accurate determination of both the supply and demand sides of the technical personnel equation. Also needing investigation is the possibility, even the desirability, of the shift of technical personnel from a less fruitful research area to one which shows more promise for major breakthroughs. Such considerations as the above have generally not been addressed in the dialogues related to national needs for future technical talent, and they need addressing in a variety of forums.

If we can provide you with any other information, please let us know. We appreciate the opportunity to address these matters of mutual interest.

Sincerely,

John A. Dutton/mg

John A. Dutton
Member, Space Studies Board

Senator GORE. Thank you, Dr. Dutton.

We will recess for 15 minutes.

[Recess.]

Senator GORE. The subcommittee will come back to order. I apologize for the more lengthy recess than I had anticipated because instead of one vote we had several votes in a series. They put off the votes on amendments to the Hatch Act reform bill until the afternoon and we are now in the middle of a series of them. There is nothing I can do about that.

After the second vote in the series, I attempted to assess how much time we would have until the series continues. There are going to be other votes. As best I can judge it, we are going to have no more than 15 minutes in which to complete what we are doing before there is another series of votes.

I think it makes sense, all things considered, to try to wrap the hearing up during that period of time and submit the questions I had hoped to be able to ask you in writing for your responses to be included in the record. I wish we did not have to do it that way because we could have a productive interchange here, but you know how this place is sometimes, and today is one of those times unfortunately.

So if both of our remaining two witnesses on this panel could summarize your statements in the time remaining, perhaps then we will have time for a few questions.

Otherwise we will just finish up in the time we have and do it entirely in writing. I am sorry for that being the way it is, but that is the way it is.

Dr. Coleman? Well, Dr. Mason, are you prepared to go next?

Dr. MASON. Yes, I can comment next.

Senator GORE. All right, fine. I see you have your paper out there. We will go with you and then Dr. Coleman. If you could summarize your statement, we will put your full statement in the record. You may proceed.

STATEMENT OF GLENN MASON, ASSOCIATE PROFESSOR OF PHYSICS, UNIVERSITY OF MARYLAND, REPRESENTING THE SPACE SCIENCE WORKING GROUP, ASSOCIATION OF AMERICAN UNIVERSITIES

Dr. MASON. Mr. Chairman, thank you for the opportunity to testify. I am going to abbreviate the remarks I had prepared. I would just like to say that my name is Glenn Mason, and I am at the University of Maryland at College Park. I am speaking here today as a member of the Steering Committee of the Space Science Working Group of the American Association of Universities. This group represents the major research universities in space science in the United States.

I would like to move over the portions of my testimony that focus on the very positive aspects of the space science program or that were summarized by Len Fisk earlier this afternoon, and also by John Dutton, and focus, while keeping that positive view in mind, on the concerns that the Space Science Working Group has in certain areas of the fiscal year 1991 budget.

Senator GORE. If you could try to do it in three minutes, then we could have three minutes for Dr. Coleman.

Dr. MASON. Fine. The foremost concern that we have is the constrained research and analysis, or R&A grants program. The clearest example of this problem is in planetary science which will sustain a real decrease for the second year in a row.

The situation is aggravated by the fact that several important programs are not in the budget as submitted, including the Magellan Extended Mission and the placement of U.S. instruments on the Inter-Cosmos and Mars 1994 mission.

In addition, the international mission line that we supported last year, is again missing from the budget. It means that support for a number of ongoing modest experiments on foreign missions must come from already overstrained R&A budgets, and as a result the university grants program will suffer.

As we see it, Mr. Chairman, a large contributor to the R&A program problems appear to be that major NASA missions are being conducted without the provision of adequate program contingencies. During the last year the launch delays of the space telescope, COBE and GRO, and the Gramm-Rudman sequestration and drug tax resulted in severe fiscal strains within the Office of Space Science.

To cope with these problems and to maintain the schedules of the flight programs there were a series of funding raids which fell disproportionately on the budgets of the university resources, especially those from planetary science and space physics communities.

Two such programs that were killed were Global Heliosphere and most of the Max 1991 balloon program for studying the current sunspot maximum.

The Space Science Working Group urges NASA to consider fully the impact of such actions and that contingencies be built into the operating plan to help the unexpected.

We are also concerned with the low level of advanced technology development (that will be needed to support the fourth great observatory, SIRTF) and also with the fact that the SOFIA mission mentioned earlier is not in the budget.

Also, while we are enthusiastic about the impact of the Space Exploration Initiative, we are concerned about two aspects of it: First that the life science program and some parts of the planetary program may be tied, perhaps to their peril, to the SEI start; secondly, we believe that the core program for the space science and applications should be seen as something to be preserved as approximately 20 percent of the NASA total and that the presidential initiatives be seen as additions. That is a point that John Dutton made earlier.

We think basically, Mr. Chairman, that there is an excellent opportunity with the new launches to enter into a new golden age of space science, but the real way to bring students into this program and new researchers is to have active on-campus activities in this area where people can see and gets hands on experience and get turned on by the space program, either to lead into that area professionally or in related areas in science and engineering.

The R&A programs in fact need to be strengthened so that the young faculty sees space science as an attractive area to enter and can carry out successful research programs in that area.

We believe then that, in fact, the best way to carry out the new initiatives seen for the next decade or two is to strengthen the university base and, in fact, only in this manner will it be possible to capture the talent and personnel that are required to make the long-term programs successful.

Our basic recommendations for the 1991 budget would be to adopt the OSSA budget at the requested level, first. Then to consider funding the R&A analysis lines at something closer to the real needs of the community, protect them from unexpected contingency and finally, to support the life sciences programs independent of the SEI new start and make sure that these presidential initiatives not be carved out of the existing core program.

Thank you.

[The statement and questions and answers follow:]

STATEMENT OF GLENN M. MASON, ON BEHALF OF THE SPACE SCIENCE WORKING GROUP OF THE ASSOCIATION OF AMERICAN UNIVERSITIES AND THE NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES

Mr. Chairman, Members of the Subcommittee, thank you for this opportunity to testify on the subject of NASA's Space Sciences and Applications program. My name is Glenn Mason, and I am an Associate Professor of Physics at the University of Maryland, College Park. I am speaking here today as a member of the Steering Committee of the Space Science Working Group (SSWG), the primary university-based research group concerned with NASA, under the auspices of the Association of American Universities. I am testifying on behalf of the Association of American Universities and the National Association of State Universities and Land-Grant Colleges, whose members represent most of the major research universities in the United States.

After an extended hiatus in the U.S. space program, this past year has witnessed the long awaited return to exciting accomplishments for the space sciences. The successful launches of the Magellan Mission to Venus, the Cosmic Background Explorer, the Galileo mission to Jupiter and its satellites, and the Hubble Space Telescope, have put into place missions which promise fascinating new observations to be carried out over the decade of the 90s. The tremendous public interest in the Voyager flyby of Neptune last summer showed once again the ability of space exploration to inspire our citizens while at the same time broadening our view of the universe. The full payoffs from Voyager came many years after its launch, and, similarly, to fully exploit the new missions, and maintain a viable and vigorous future program, we need to plan ahead.

In discussing the NASA Space Science and Applications program, it is important to review the rationale for a vigorous space program.

The Importance of a Vigorous Space Program

As an element of national policy, a strong and active space program provides a highly visible demonstration of this nation's scientific and technological prowess and its determination to maintain its status as world leader. At an intellectual level, space science epitomizes our innate inquisitiveness about our environment and our place in the cosmos. At a technological or engineering level, space presents profound challenges that drive industrial creativity. At an emotional level, space offers the unique opportunity for all of us to experience the thrill of exploration of an expanding frontier, and the enrichment which accrues from observations of the wonders of other worlds. The U.S. space program must achieve a balance among these perspectives, which calls, in turn, for a balance between science and applications, between manned and unmanned activities in space, between large complex missions and small rapid turn-around missions (eg. suborbital programs), and between infrastructure and new initiatives.

The growing public concern over the fate of our own planet underscores the crucial role of space science for understanding our world. With issues such as the deterioration of the ozone layer and secular global warming drawing accelerated worldwide attention, the space science community will bear an increasing responsibility to provide the technical context for political decisions at national and international levels. Our national space program must continue to seek the new data necessary to provide this context. It is relevant to consider that when the nation's space program got under way in the 1950's environmental concerns were not a broad public policy issue. The ability of the current space technology to monitor the environment is a good example of an unexpected benefit which resulted from carrying out research initiatives.

A robust space science program also can help address another pressing national priority -- the need to reverse the declining interest and skill in science and mathematics in the upcoming generation. Almost daily we read of a new study showing that the math and science skills of our young students lag far behind those of other countries. It is essential to strengthen those national programs that capture the scientific and technical imagination of our population. Our space program has been and can continue to serve as a catalyst in this area. One need look only at the continued large crowds at the National Air and Space Museum, public fascination with discoveries of a new supernova, the complex atmosphere of Neptune, or activities such as the launch of the Hubble Space Telescope to recognize the power of space science to drive the curiosity of child and adult alike.

It is within this context that I, on behalf of the SSWG, would like to offer the following comments on the FY'91 NASA budget before you.

Strengths of the Proposed FY'91 NASA Budget

At the outset, I should emphasize that the Space Science Working Group recognizes the strong support for space science in the FY'90 budget which is currently being implemented by the Office of Space Science and Applications (OSSA) within NASA. We particularly applaud the new start for the CRAF/Cassini missions, the diversification of the launch vehicle fleet, the movement of science onto ELVs, the provisions for small missions in space physics and astrophysics with the enhanced explorer program, the restoration of Gravity Probe B, support for the Total Ozone Mapping Spectrometer (TOMS) and enhancements of the science research infrastructure.

I would now like to focus on the proposed FY'91 NASA budget in the context of how responsive it is to the various objectives of the space program. The SSWG commends NASA and President Bush for submitting a FY'91 budget which allows for continuation of programs already underway, provides for a balanced program across the disciplines of space sciences and applications, and allows a new start for the Earth Observing System (EOS). This new start represents both the next step in the long-range OSSA strategic plan and the cornerstone for the Global Change Research Program. The budget also provides a new beginning for the Space Exploration Initiative (SEI), announced by the president and of particular interest to the Life Science and Planetary Science programs.

I will briefly summarize how the budget, in conjunction with the strategic plan, benefits the various Space Science and Applications disciplines:

In *Physics and Astronomy*, the budget request supports the enhanced Mission Operations and Data Analysis (MO&DA) needs of the Hubble Space Telescope (HST), and other missions to be launched this year: namely the German/US x-ray telescope ROSAT, the Combined Release and Radiation Effects Satellite (CRRES), and the second of the Great Observatories, the Gamma Ray Observatory (GRO). It allows for the final installment of the enhancement of the Explorer program to accommodate the newly constituted Small Explorer program (SMEX). The SMEX program is of particular importance to university-based science and engineering groups: it is also an excellent vehicle for the training of future scientists because it provides moderate missions that are scientifically focused and involves time scales commensurate with graduate student participation. The budget allows for the continued development of the previous new starts for the Global Geoscience (GGS) mission in space physics and AXAF, the third of the Great Observatories.

In *Planetary Science*, the budget provides for the MO&DA support for the recently launched Magellan and Galileo missions to Venus and Jupiter. It provides necessary funds for the long-delayed launch of the Ulysses mission and the continuation of last year's new start for the CRAF/Cassini mission. Within the framework of SEI, funds are requested to begin development of the Lunar Observer as well as to enhance the Mars Observer science payload and ground system.

In *Life Science*, the budget request provides a significant increase, partly to make up for funds not granted in FY'90 and partly to allow the two imminent life science missions on Spacelab (SLS-1 and IML-1) to be conducted. A modest start of a dedicated and reusable satellite experiment, Lifesat, is also included. SEI will support Extended Duration Studies and Centrifuge Development on the Space Station as well as a Biomedical Monitoring and Countermeasures (BMAC) program.

In *Earth Science*, the budget provides for the new start for the major EOS program, which will eventually double the number of university researchers using space techniques in the earth sciences. The budget provides for continued support for the TOPEX and UARS missions. In addition, a new small satellite program, Earth Probes, is to begin. This program is as ideal for university participation and the training of future scientists as the Explorer program is for Physics and Astronomy.

Concerns for the FY'91 Budget

Mr, Chairman, as I have said, we believe that the proposed FY'91 budget does provide for the continued implementation of the OSSA Strategic Plan, and we are excited about the new Presidential Initiatives. However, there are additional concerns, not addressed by the budget request, which are of great importance to the university space science community. The SSWG urges that these be considered.

Foremost is the highly constrained R&A grants program. The clearest example of this problem is in Planetary Science, which would sustain a real decrease for the second year in a row. This situation will be aggravated by the fact that several important programs are not in the budget as submitted, including the Magellan extended mission and the placement of U.S. instruments on the Intercosmos- Mars '94 Mission. The lack of an "International Missions Line," supported by the SSWG last year, means that support for a number of on-going modest experiments on foreign missions must come from already overly strained R&A budgets; as a result important university grants programs suffer.

Mr. Chairman, as we perceive it, a large contributor to the R&A problem appears to be that major NASA missions are being conducted without the provision of adequate program contingencies. For example, during this past year launch delays of HST, COBE and GRO, GRH sequestration and the "drug tax" have resulted in severe fiscal strains within OSSA. To cope with these pressures, maintenance of the big program schedules resulted in funding "raids" which fell disproportionately in the budgets of university researchers, especially those from the planetary science and space physics communities. Two such programs that were killed were the Global Heliosphere and most of the Max '91 (for the current solar maximum study). This was a painful blow to the individual investigators and their students, one we would like to prevent from happening again.

The SSWG urges NASA to consider fully the impact of such actions and that contingencies be built into the NASA operating plan.

In addition to the ongoing R&A problems, the budget request for the development of future components of the Strategic Plan appears to be low. Enhanced Advanced Technology Development (ATD) funds necessary to prepare technologies for the fourth great Observatory, SIRTF, were not included, nor was the proposed SOFIA mission. SOFIA is ideal for hands-on training of future generations of space scientists, and a significant portion of its total development cost would be borne by the Federal Republic of Germany. Expanded opportunities for developing new technologies and training of experimenters (e.g. in the sub-orbital program) are not adequate to meet future needs.

Another victim of budgetary pressures in OSSA is the cancellation of the ASTRO-2 mission in the FY'91 budget to accomplish a $10 M savings; it was hoped that this PI-class mission with broad university involvement and support could be reflown in FY'92 or FY'93 and the investment in the hardware and science fully realized.

The SSWG is enthusiastic about the potential impact of the Space Exploration Initiative. As it presently appears in the FY'91 budget, however, two areas of general concern have occurred to us. Firstly, the long- overdue support for the Life Science program, as well as some components of the Planetary program, are perhaps tied dangerously to the SEI start. Secondly, we feel that a balanced core program for space science and applications be preserved (e.g. with the OSSA budget for the core program continuing at approximately 20% of the NASA total) and that the major initiatives of the Global Change Program and SEI not displace this.

A Strengthened Academic Participation in the Space Science

Mr. Chairman, as we consider the dazzling series of new space science missions launched this past year, along with those under development, coupled with the bold initiatives for the EOS and SEI, many of us in the space science community view our present time potentially as the start of a second "golden age" of space science in the United States. To carry out these programs, however, requires highly trained personnel which can only come from the University base. Yet, Mr. Chairman, for over a decade universities have witnessed a steady decline in the number of U.S. graduate students entering such basic science and engineering fields: Furthermore, a recently released AAU report, "The PH.D. Shortage: The Federal Role," projects a severe shortage of PH.D.s in the coming decade. The projection is based on data from the National Science Foundation and "Prospects for Faculty in the Arts and Sciences," by William Bowen and Julie Anne Sosa. Thus, we can conclude that our existing system is not well positioned to provide the human resources which will be necessary to carry out these national programs.

How can these trends be reversed? A vigorous national space program is necessary to help reverse these downward trends by igniting the curiosity that will attract many students to careers in science and engineering. Federal support is needed for academic programs at all levels, including the graduate level. Once at a university, students are attracted to space research by opportunities for "hands-on" experience in research programs on the campus. Students respond to tangible "access to space" research activities.

Once attracted to the field, some of these students will continue their careers in space science research if, and only if, they foresee attractive career opportunities. To the extent that they witness long delays, sudden cancellations, and chronic shortages of R&A support, many students will choose alternative career paths. The situation is augmented by the fact that the NASA fellowship program is oversubscribed. We need to make space science an attractive field to young researchers if we are to carry out these programs

Thus,we believe the best way to carry out the program is to continue strong university participation in all aspects of space science research, and to ease the serious shortages of grant support in order that young people may see this area as one they want to enter. Only in this manner will it be possible to train the people needed to carry out the long term program; and only by involving the universities in this manner will NASA be able to capture the innovative ideas that will be required to make the long term program a resounding success.

Overall Recommendations

The proposed FY'91 budget will allow continued implementation of a long-term plan that will return this nation's program in space science to one of vision and vitality. The plan remains responsive to the recommendations of NASA and National Academy of Sciences (NAS) scientific advisory committees. Therefore, the SSWG urges that the FY'91 budget for OSSA be adopted at the requested level.

We also ask that the Research and Analysis (R&A) lines be funded at levels closer to the needs of the community, and that they be protected from unexpected contingencies. Previous cutbacks have seriously affected the infrastructure of space science at the nation's universities where not only the future generation of space scientists, but scientists and engineers generally, are educated and trained.

We feel that support for the Life Sciences is overdue, and we request that both the Life Science and Planetary Science programs be considered important, independent of the Space Exploration Initiative (SEI). The addition of new initiatives such as the Global Change Research Program and SEI should not be made at the expense of a balanced core program; the core program must be retained at least at the historical levels of support within NASA

Thank you again for the opportunity to present this testimony. I would be pleased to answer any questions.

Subcommittee on Science, Technology and Space
of the
Committee on Commerce, Science and Transportation

Follow-up Questions to May 10, 1990 Hearing
Submitted by Senator Al Gore

Responses by
Dr. Glenn Mason

Associate Professor of Physics
University of Maryland, College Park
on behalf of the
Space Science Working Group
of the
Association of American Universities
and the
National Association of State Universities and Land Grant Colleges

FUTURE OF SPACE SCIENCES

IN 1988 THE SPACE STUDIES BOARD COMPLETED A MULTI-VOLUME REPORT ENTITLED "SPACE SCIENCE IN THE 21ST CENTURY: IMPERATIVES FOR THE DECADES 1995-2015." THE REPORT DISCUSSED FUTURE RESEARCH NEEDS FOR EACH OF THE VARIOUS AREAS OF SPACE SCIENCE, MAKING RECOMMENDATIONS FOR ACTION.

- TWO YEARS LATER, HOW WOULD YOU VIEW THE HEALTH OF NASA'S SPACE SCIENCE RESEARCH PROGRAMS? HOW DOES IT COMPARE TO PREVIOUS YEARS ?

Answer: The last 12 months or so have seen a breathtaking recovery of the space science program as missions originally scheduled for launch in the 1980s got underway: Magellan, COBE, Galileo, HST. Before the end of this year, CRRES, Ulysses, and GRO will be launched. There is a tremendous rebirth taking place and the entire space science community is exhilarated about it. Of course, this pulse of activity is making good on the promises of the last decade.

Looking to future initiatives, we are benefiting from the leadership of Dr. Lennard Fisk. He has led OSSA to propose a bold, and comprehensive program for maintaining U.S. leadership in space science during the coming decade. With the support of Congress, this has included major new starts (ISTP, AXAF, Craf/Cassini, EOS), a scientific program for the Space Station, and enhancement of small programs such as the Explorer Program, and, more recently, the Earth Probe series. The orderly implementation of the OSSA Strategic Plan will ensure a healthy space science research program through the end of the century. This outlook is a great improvement over the situation of just a few years ago, when the health of the entire program was in doubt.

• IN ADDITION TO THOSE SPECIFIC MATTERS YOU DISCUSSED IN YOUR TESTIMONY, ARE THE PRIORITIES BEING PURSUED BY NASA CONSISTENT WITH THE OBJECTIVES OF THE RESEARCH COMMUNITY?

Answer: Managers in the OSSA consistently point out to their scientific advisory panels that "NASA does missions, not scientific research per se". Many of the large NASA programs (Apollo, Shuttle, Space Station, SEI) have their origin in national political priorities, and were not outgrowths of the scientific community. Therefore, no one can reasonably expect there to be a perfect match of NASA programs and the wishes of the community.

Speaking from the University research community, many researchers would be better served if a larger fraction of the OSSA effort were devoted to the smaller missions, rather than major projects which typically have modest university participation. The very severely constrained R&A grants program is an example of an ongoing problem wherein OSSA obligations to support new flight programs cuts off the small R&A grant funding levels at very small overall savings.

To demonstrate how bad this situation can get, let me give a current example. In March, 1990, NASA solicited proposals for a Guest Investigator Program (GIP) in the Space Physics Division to support data analysis on some excellent satellite data sets (AMPTE, Dynamics Explorers 1/2, ISEE 1/2, ICE, IMPs 7 & 8, San Marco D, and Atmospheric Explorers). For the available $1.5M in this program, NASA has received 144 letters of intent; if distributed in $60K grant sizes (which is about the minimum size with which something meaningful can be accomplished), only 17% of the proposals could be supported. In addition, the Principal Investigator teams in these programs are having their funding cut radically this year, and are being told to apply for the GIP.

This situation illustrates that NASA and the research community's needs can be, but often are not, consistent. An irony of this situation is that typically solutions to these problems would require funding levels which are modest compared with the OSSA program, and so the problem appears to be one involving priorities more than funds.

FUNDING PRIORITIES

AS WAS DISCUSSED WITH DR. FISK, NEXT YEAR'S BUDGET REQUEST FOR THE SPACE SCIENCE AND APPLICATIONS PROGRAMS, LIKE ALL OF NASA, HAS RECEIVED A HEALTHY INCREASE OVER THE CURRENT FISCAL YEAR. HOWEVER, IN THIS DAY OF GRAMM-RUDMAN, IT'S IMPERATIVE THAT WE ESTABLISH FUNDING PRIORITIES.

•HOW WOULD YOU PRIORITIZE NASA'S FUNDING REQUEST FOR THE COMING FISCAL YEAR? HOW IMPORTANT IS THE SPACE SCIENCE AND APPLICATIONS PROGRAM TO YOU AND THE UNIVERSITIES YOU REPRESENT?

Answer: To answer the second question first, the space science and applications program is absolutely of vital importance to the university research programs represented by members of the Space Science Working Group (SSWG).

As for priorities, the Space Science Working Group supports the OSSA request for the coming fiscal year. Our primary concern is in the area of the missions being done, and they in turn are the outcome of extensive coordination with the NAS boards, and NASA's own scientific advisory panels. The SSWG has never sought to second guess the end recommendations of that careful planning process.

However, we have often stated our concern that certain NASA programs (Shuttle, Space Station) which are carried out primarily for national political reasons, may squeeze the space science budget when they get into cost or performance problems. In this sense, the SSWG members are generally more supportive of the dedicated scientific missions, and that implies some sense of priority in the OSSA plan. In the case of huge programs like Space Station or SEI, the scientific community hopes that NASA and the Congress will take advantage of the scientific opportunities presented by these programs, and will fund appropriate space science investigations from the outset.

- DR. MASON, YOU EXPRESSED.YOUR SUPPORT FOR THE PROPOSED MANNED MISSION TO THE MOON AND MARS. GIVEN THE REAL POSSIBILITY OF FUNDING LEVELS FOR NASA BELOW THE PRESIDENT'S REQUEST, WHERE WOULD YOU PUT MOON/MARS MISSION ON YOUR LIST OF PRIORITIES?

The SSWG supports the SEI, which is of particular interest to the Life Science and Planetary Science programs. This program, of course, will require a huge, and ongoing national commitment to carry out successfully, and even then the payoff will not be seen till well into the next century. That makes the SEI a somewhat more risky venture than, e.g., the major missions being executed under the OSSA Strategic Plan. Personally, I would not be willing to sacrifice the nearer term program for the mere hope that SEI will be carried out as proposed. I suspect that the Life and Planetary Science researchers in the SSWG would also point out that they can reach many of their research goals without depending on SEI, and, indeed, the SSWG statement on the FY91 budget points out that the Life Science initiatives should not be dependent on SEI.

If the SEI is carried out, there will be some excellent research opportunities, but it has too long term a payoff to be put at the top priority. University researchers cannot wait until 2010-2020 for the next exciting results -- the university programs would all have closed down long before then without exciting missions coming along regularly.

- DR. MASON, YOU ALSO DISCUSSED THE NEED TO PROTECT UNIVERSITY RESEARCH GRANTS. HOW CAN WE ACHIEVE THE BALANCE THAT YOU SUGGEST IS NEEDED BETWEEN BIG PROGRAMS THAT ARE DRIVEN BY SPACECRAFT DEVELOPMENT SCHEDULES AND UNIVERSITY RESEARCH GRANTS?

Every year the SSWG has pointed out a number of cases where excellent science programs were being cut back or canceled to save relatively small amounts of funding.

The most spectacular case was probably the U.S. Solar Polar spacecraft, but smaller cases occur routinely in the suborbital area. Achieving the required balance requires an adjustment of priorities within the planning process at OSSA -- the current situation is not working well even though "carrying out the ongoing program" is one of the basic goals of the Strategic Plan. So I would hope that the OSSA managers would be willing to give up something of the flight hardware front in order to address this.

Last year's problems came from slips in HST, COBE and GRO. Use of expendable launch vehicles (as will be done for most future programs) will help remove some of the slips which result from reliance on the Shuttle of the Space Transportation System; in addition, a greater emphasis on smaller programs would help keep problems to a more manageable size.

EDUCATION

•YOU KNOW FIRST-HAND THE PROBLEMS OF DECLINING NUMBERS OF GRADUATE STUDENTS IN THE TECHNICAL FIELDS OF MATH, SCIENCE AND ENGINEERING. BEING ON THE FRONT LINES, SO TO SPEAK, YOU ARE UNIQUELY POSITIONED TO HELP US DIRECT NASA AND THE FEDERAL GOVERNMENT TO SPECIFIC INITIATIVES THAT SHOULD BE TAKEN TO REVERSE THAT TREND.

• WHAT SUGGESTIONS DO YOU HAVE FOR THIS SUBCOMMITTEE TO BETTER UTILIZE THE RESOURCES OF NASA AND THE SPACE PROGRAM IN ORDER TO INCREASE THIS NATION'S POOL OF TALENT IN THE FIELDS OF SCIENCE, ENGINEERING AND MATH? HOW IS NASA DOING IN THIS REGARD TODAY?

Answer: I believe that one of the main benefits of the NASA space science program lies in its ability to inspire our citizens and ignite the curiosity of young and old alike. There is evidence of this all around, most recently with the tremendous interest shown in the launch of HST and the promise it holds for exciting new discoveries in the years ahead. From personal experience, I know that this sort of thing can capture the interest of young people -- and some of them may enter technical fields and perhaps even space research itself as a result.

Once a student arrives on a college campus, the decision to enter a technical field may hinge on being exposed to research opportunities where they can get some "hands-on" experience. Many students who go into graduate research in our discipline chose it because of an undergraduate job at another institution. At the University of Maryland space physics group, for example, we employ about 20 undergraduates, majoring in technical fields, for part time work in support of NASA flight projects. This brings the excitement and realism of cutting-edge technology on campus, and is a very positive influence. Only in programs where universities can contribute to flight hardware is this sort of activity possible.

Ultimately, a healthy NASA space science program will be the best incentive for generating student interest. There are some significant other moves which could be taken -- for example, increasing the number of NASA graduate student fellowships (the current number is pitifully small compared to the NSF, despite the fact that the NASA R&D program is much larger).

•HOW WOULD MAJOR FUNDING REDUCTIONS TO SPACE SCIENCE AND APPLICATIONS PROGRAMS AFFECT THE NUMBERS OF GRADUATE STUDENTS ENTERING TECHNICAL FIELDS?

Answer: These funding cuts, of course, would seriously reduce the number of graduate students entering a particular discipline -- cuts in funding for plasma fusion research is a current example of that cause/effect relationship. Eventual employment opportunities are very much on the mind of graduate students, and a dismal funding picture will push people into other areas. Space science has suffered from this along with the general perception of problems arising from the shuttle disaster.

Senator GORE. Having read your statement, I think you managed to hit all the high points in that brief period of time. Thank you very much. The bell for the vote rang even quicker than I was afraid of, and that is when I abbreviated the time even more, and I hate to have to do it this way. I will say again, Dr. Coleman, we will turn it over to you for four minutes, if you can.

STATEMENT OF DR. PAUL J. COLEMAN, JR., DIRECTOR, INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS, UNIVERSITY OF CALIFORNIA, LOS ANGELES, CA, AND PRESIDENT, UNIVERSITIES SPACE RESEARCH ASSOCIATION

Dr. COLEMAN. As you know, I had intended to talk about the small mission component of NASA's program. I wanted to do two things, one to urge your support for that component, which I think is very important, and the other to suggest some ways to strengthen it. Instead I am going to be very blunt about the related problems, in the interest of saving time.

I believe these small mission elements are needed in every single component of NASA's effort: In life sciences, Mission to Planet Earth, exploration, etc. There is not a single element of the space flight program, that I can think of, that would not gain from a strengthened small missions element.

The problem that I have with the program as it stands now is that the unmanned component is still too big and it is still too expensive. Dr. Fisk mentioned $300 million a year that OSSA expends in support of university-based activities. The present small explorer program is running $20–$30 million a mission, which means 10 to 15 a year at most, even if we could use the entire $300 million on small explorers. That is just not cheap enough, if we are going to do the kinds of things that I advocate in my written testimony.

In the same vein, I am worried about small launch vehicle developments that are on going. They are moving in the right direction, but I keep hearing on the grapevine numbers like $10 and $20 million per launch. We just cannot make do with that. We do not need any more $10 million vehicles. We need $1 million vehicles. I thank you for your time.

[The statement and questions and answers follow:]

STATEMENT OF PAUL J. COLEMAN, JR., DIRECTOR, INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS, UNIVERSITY OF CALIFORNIA AT LOS ANGELES

Mr. Chairman, members of the subcommittee, ladies and gentlemen; it is a privilege to have this opportunity to appear today.

I have been asked to discuss NASA's Space Science and Applications program. In particular, I have been asked to comment on NASA's effort to develop an effective, coordinated, and logically phased research program, as well as how current programs could be improved.

Given the limitations on time, I should like to devote my prepared remarks on the component of NASA's program that has come to be called "small missions." For reasons that I will discuss shortly, I believe that an appropriately constituted program of small, low cost space flight missions is essential to the health of university-based space research and development.

As you know, for the near term, NASA is emphasizing the role of small missions in the Mission to Planet Earth which, as you also know, is NASA's contribution to the national research initiative on global change. In the earth sciences and applications program, which includes Mission to Planet Earth, these small missions have been designated "Earth Probes." A series of these Earth Probes is already tentatively scheduled. In the space physics program, a small missions component designated "Small Explorers" is well along. We are off to a good start.

However, in order to realize the full potential of the small missions component, we must introduce some significant changes. Firstly, we must make small missions more plentiful. Secondly, we must make the small missions cheaper. The small missions under current consideration are for the most part simply smaller, scaled-down versions of the larger missions. There is too little innovation in the approach to design, fabrication, reliability, and quality assurance. There is too little use of new technology. Consequently, these small missions cost must more then they should.

A Problem.

The larger-scale missions in the unmanned program have become so complex and so expensive, that we cannot afford to have one fail. We have set a goal of essentially zero failures and, as a result, these projects have become even more expensive. In our efforts to reach this goal, only professionals and only the best professionals at that can participate in the design, fabrication, launch, and operation of these magnificent machines. They are properly and, in fact, necessarily the products of high-tech industrial concerns and national laboratories.

Thus, we are bound by a chain of conventional wisdom and correspondingly, conventional ways of working in space. A conventional rocket launch costs a lot of money, too much to be used for a cheap spacecraft. Consequently, we need a space flight mission that is worthy of an expensive launch vehicle.

The spacecraft for this worthy mission is generally complex, and therefore expensive as well. At this point, we have a system consisting of launch vehicle and spacecraft that is *very* expensive. Therefore, we must spend considerably more to make certain that it does not fail. At this point, we have a system that is *very*, *very* expensive.

By the way, because the system must not fail, we had better not use any newfangled hardware or subsystems in it. We had better use "space qualified" or "mil. spec." hardware. And, by the way, we are a little behind in our program for qualifying this hardware, so this expensive system must be built from hardware that was designed five or ten years ago. And, by the way, nobody else uses this old stuff anymore, so if you want to use it you have to pay extra.

The message is clear. Expense begets expense.

There is, of course, the other side of the coin. This conventional wisdom was learned in the school of hard knocks. We have done wonders in space because we learned it and learned it well. And it is still applicable to much of our space-flight program. Consequently, I do not suggest for one minute that we eliminate this more conventional approach to space flight. I suggest only that we recognize that other approaches have their places in this great endeavor.

We are not looking hard enough for better ways. There is no component of the program in which we intend to learn by trying and, inevitably, failing from time to time. There is no component of the program in which we can experiment with new ways to do things.

Where do we try new ways that we believe will be better ways? How do we prove that a new way is better? Where do we try the technologies that have the potential for reducing the cost of access to space? In short, where is the school of hard knocks?

It is as though we have decided that we cannot afford to have this school. In fact, we can no longer afford to do without it.

A Solution.

We should implement a systematic evolution in the mix of unmanned space flight missions; an evolution that moves this part of the program away from larger, relatively complex missions and towards smaller, simpler missions. Clearly, we cannot begin to do everything with small missions. However, in my judgement, we are not doing nearly enough.

As we consider the unmanned missions that will be precursory and complementary to both the Mission to Planet Earth and the exploration of Moon and Mars, we should examine the advantages of such a change. In the foregoing, I mentioned the small mission elements already defined in the earth science and applications program and the space physics program.

However, there are equally important tasks for small missions in the programs of planetary exploration, astrophysics, life sciences, communications, and information systems within the office of space science and applications as well as in the various programs of the exploration and technology side of NASA's house.

In short, the small missions approach is applicable to every component of the unmanned space program. Moreover, I am convinced that, properly constituted, small spacecraft offer a more cost effective tool for many of the tasks in this program. The current, advanced state of space technology will permit us to effect this change in the mix with no reduction in our space-flight capabilities. That is to say, we can do a significant part of the work of the unmanned program with smaller, simpler spacecraft and, because of our advanced technology, we can obtain results of the same high quality.

I believe that the change that I propose in this small mission-big mission mix, coupled with the systematic incorporation of new technology and revised procedures for quality assurance in the small mission component, would make the civil space program:

- A more cost-effective source of space-related research and development, in particular,

  A place to do small science.

  A place to try new technology.

- A more effective partner in education and training of advanced students in engineering and science.

- A place to encourage the entrepreneurial development of low-cost access to space.

- An even more exciting place to work.

In what follows, I should like to discuss in somewhat more detail the needs for such an approach and the potential returns from it.

Research.

As President Bush stated in his recent address to the National Academy of Sciences, "One of the best things government can do to support the magnificent creativity and energy of the American technical community is to locate individual scientists with talent, and furnish them with adequate resources and state-of-the-art instrumentation.....to help these investigators make progress."

The history of research is as much a history of technology as it is a history of scientific concepts. New tools for research make possible advances in science.

The small missions are essential to the space-related element of small science. The needs of the researchers for these tools are well established. The technology to provide these tools is at hand.

Education and Training.

I believe that graduate-student education and training in a number of space-related, scientific specialties could be better served by the unmanned component of the civil space program. Reference is frequently made to the statement that balloons, aircraft, and sounding rockets are the only reasonable training grounds for experimentalists in space science. I suspect that a similar statement can be made relative to the hands-on training of engineers in space-related engineering specialties.

Accordingly, the value of small missions, as I have defined them herein, goes well beyond their utility in research and development. They are important aids in the education and training of scientists and engineers.

Moreover, they provide exactly the kind of hands-on, practical experience that is essential to our strength as a competitor in product development and manufacturing. And I believe most economists would agree that strength in manufacturing is the foundation for a high standard of living. We cannot do it with a service economy.

As an educator, an experimentalist who has flown scientific instruments on a number of NASA spacecraft, a manager of research and development, and an individual who has devoted considerable effort to studies of the processes and infrastructure of the nation's science and technology establishment, I am convinced that the change I advocate here is the single most important step that NASA could take to foster improvements in the advanced education and training of our future engineers and scientists. This change would facilitate increases in both the number of graduate-student participants and the quality of their participation.

Much has been written in recent months about the dearth of students in science and engineering and about our strengths and weaknesses as competitors in a high-tech world. There is a host of reasons for concern, but the one to which my topic is relevant is the following:

Missing in today's space program are the opportunities for graduate students in science and engineering to get the kinds of practical experience that teaches them how components are made, how components become subsystems, how subsystems become systems, how sensors sense, and how they are designed and fabricated.

This small missions' effort is so important because it is the means by which we can provide these technologists and researchers of the future with the practical, hands-on experience that they need and that we need them to have. At the same time, it is a means by which we can broaden the participation of young engineers and scientists in the nation's space program.

NASA Centers.

Let me turn now to the relevance of this concept to some other institutions, specifically the NASA centers and the Jet Propulsion Laboratory. During the past five years, I have had two occasions to visit all of the NASA centers and the Jet Propulsion Laboratory, firstly in my capacity as commissioner on the National Commission on Space and later as a member of a team appointed by the administrator of NASA to assess the quality of research at these institutions. On both occasions, we devoted considerable time to discussions with the younger engineers and scientists.

Here as well, the need for small missions is obvious. These young professionals should have the same kinds of practical, hands-on experience that is so important for our graduate students. In my judgement, it is an essential part of their preparations for their future roles in the grander endeavors of space flight.

The Small Missions Program in the Department of Defense.

The Department of Defense has recognized the value of a small missions capability through a number of activities: The Defense Advanced Research Projects Agency (DARPA) is funding technology developments in small spacecraft and small launch vehicles. The Air Force has initiated a small missions program called Space Test Experiments Platform (STEP) to be flown on an Air Force Small Launch Vehicle. Proposals for this launch vehicle will be requested later this year. The Navy has an ongoing program called Spinsat.

Cost.

To realize the full potential of small missions, we need a concerted effort to develop low-cost access to space. Simply stated, the objective of this effort would be the capability to perform small missions, including earth satellites and lunar, planetary and interplanetary spacecraft, at costs less than today's cost for one of the larger sounding rocket flights.

The cost must be low enough to permit a relatively large number of launches - a number perhaps smaller than the number of sounding rocket launches, but certainly much greater than the number of space flight missions.

Almost as important as cost is time. Today, in nearly every technological endeavor, the time from conception to operation is becoming shorter and shorter, often because of competitive pressures. In the space program, the time from a new start to lift off is getting longer and longer. We all know that time is money, so the efforts to reduce time to lift off is an essential part of the effort to cut costs.

I should add that, in the context of the tenure in graduate school of the average student in engineering and science, cutting the time to lift off is an especially important objective.

For some time now, we have had the technical capability to provide small, low-cost spacecraft for a number of tasks. (Although, as I have stated in the foregoing, we have not put this capability to proper use.) The missing element has been the technical capability to provide a small, low-cost launch vehicle.

A systematic shift towards smaller-class missions of the kind that I advocate here, missions that incorporate new technology and new approaches to quality assurance, would trigger the development of truly low-cost access to space. It would galvanize the remarkably talented and dedicated group of space "entrepreneurs" in this country, a group of engineers and scientists from government, industry, and the universities who have never given up on “cheap space.”

Recent developments in this connection are promising indeed. NASA has recently released a request for proposals for a new generation of small, expendable launch vehicles to provide truly low-cost access to low-earth orbit. DARPA has started down the same path, with two efforts. As mentioned above, the Air Force will shortly release a similar request.

The efforts by government agencies and the interest, and indeed activity, in industry indicates that this missing component will not be missing for long. However, we must work hard to make certain that we are taking a step in the direction suggested herein. We must not find ourselves with the scaled-down versions of today's launch vehicles, designed and built in the conventional ways. We do not need ten-million-dollar vehicles. We need one-million-dollar vehicles.

Mr. Chairman, members of the subcommittee, thank you again for this opportunity to appear.

Questions for Dr. Paul Coleman
Hearing on Space Science and Applications
Submitted by Senator Al Gore
May 10, 1990

Future of Space Sciences

1. In 1988, the Space Studies Board completed a multi-volume report entitled "Space Science in the 21st Century: Imperatives for the Decades 1995-2015." The report discussed future research needs for each of the various areas of space science, making recommendations for action.

   - o Two years later, how would you view the health of NASA's space science research programs? How does it compare to previous years?

   - o In addition to those specific matters you discussed in your testimony, are the priorities being pursued by NASA consistent with the objectives of the research community?

Funding Priorities

As was discussed with Dr. Fisk, next year's budget request for the Space Science and Applications programs, like all of NASA, has received a healthy increase over the current fiscal year. However, in this day of Gramm-Rudman, its imperative that we establish funding priorities.

- o How would you prioritize NASA's funding request for the coming fiscal year? How important is the Space Science and Applications program to you and the universities you represent?

Education

You know first-hand the problems of declining numbers of graduate students in the technical fields of math, science, and engineering. Being on the front lines, so to speak, you are uniquely positioned to help us direct NASA and the Federal government to specific initiatives that should be undertaken to reverse that trend.

- What suggestions do you have for this Subcommittee to better utilize the resources of NASA and the space program in our effort to increase this Nation's pool of talent in the fields of science, engineering, and math? How is NASA doing in this regard today?
- How would major funding reductions to the Space Science and Applications programs affect the numbers of graduate students entering technical fields?

Smaller Satellites

Dr. Coleman, you articulated the need for smaller satellites and the benefits they can generate both in our effort to attract more students to the sciences and to the space program as a whole.

- Where would you draw the line in your effort to downsize spacecraft? For example, NASA has justified both of the EOS polar platforms on various scientific, engineering, and budgetary arguments, an approach which has tentatively been confirmed by the National Research Council. How do you respond to the justified need for such larger platforms?

Future of Space Sciences

1. In 1988, the Space Studies Board completed a multi-volume report entitled "Space Science in the 21st Century: Imperatives for the Decades 1995-2015." The report discussed future research needs for each of the various areas of space science, making recommendations for action.

   o Two years later, how would you view the health of NASA's space science research programs?

During the past two years, the health of these programs has improved considerably. Most of the improvement is a direct consequence of the launching of a number of major space-flight missions, many of which had been delayed by the Challenger accident.

o How does it compare to previous years?

In comparison with the post-Challenger years that preceded the report, the health of the space-flight component of these programs is now much better. In comparison with the five years before Challenger, their health is now about the same.

o In addition to those specific matters you discussed in your testimony, are the priorities being pursued by NASA consistent with the objectives of the research community?

NASA's priorities, more specifically those reflected in OSSA's programs, are otherwise consistent with the objectives of the research community, especially the priorities associated with the major flight projects. As you know, there is a considerable and continuous dialogue between NASA and the community on such matters. The mismatch develops in the implementation of these projects. When one of these projects gets into money trouble, and the money cannot be found among the flight programs without doing them harm, the research and analysis budget takes a hit.

This decision may not be wrong. In fact, it may well be the most cost effective choice. However, the net result is that, in practice, research and analysis has the lowest priority. I do not believe that position is consistent with the views of the research community.

The foregoing remarks apply to the OSSA programs. Overall, the research community would prefer that a smaller fraction of the funds be devoted to what has come to be called "operations" and a greater fraction devoted to R & D.

Funding Priorities

As was discussed with Dr. Fisk, next year's budget request for the Space Science and Applications programs, like all of NASA, has received a healthy increase over the current fiscal year. However, in this day of Gramm-Rudman, it's imperative that we establish funding priorities.

o How would you prioritize NASA's funding request for the coming fiscal year?

I have not studied the many elements of the proposed program carefully enough to be able to respond.

o How important is the Space Science and Applications program to you and the universities you represent?

OSSA funds the bulk of the space-related research that is conducted by universities in the U.S. I do not have the figures that would allow me to be specific about the situations at the sixty-seven universities in the Universities Space Research Association. However, at UCLA, for example, NASA funds about three percent of all of the sponsored research. OSSA probably funds ninety percent of that fraction.

Education

You know first-hand the problems of declining numbers of graduate students in the technical field of math, science and engineering. Being on the front lines, so to speak, you are uniquely positioned to help us direct NASA and the Federal government to specific initiatives that should be undertaken to reverse that trend.

o What suggestions do you have for this Subcommittee to better utilize the resources of NASA and the space program in our effort to increase this Nation's pool of talent in the fields of science, engineering, and math?

NASA can improve the quality of the participation of graduate students and entry-level professionals in these fields.

My plea for increased access to space for small science and technology is motivated by my belief that this increase would greatly enhance the quality of their participation. At the same time, I am convinced that the objectives of each and every division in OSSA, as well as a number of programs in the Office of Aeronautics, Exploration, and Technology, would be better met by a flight program that included more, smaller missions.

In addition, the engineers and scientists who go to work in these fields after completing their studies, including those who go to the NASA centers, are too often assigned to jobs that do not foster technical and scientific growth. Worse, some of these jobs consist primarily of paperwork related to project management.

o How is NASA doing in this regard today?

On the issue of the quality of the jobs for entry-level professionals in these fields, NASA, along with the rest of the Federal agencies and the aerospace and defense industries, could do much better. Too many of these jobs are turn offs. At the same time, the Nation cannot afford to let these people be lost to other, non-scientific and non-technical fields.

On the closely related issue of access to space for small science and technology, as I stated earlier, NASA is doing poorly.

o How would major funding reductions to the Space Science and Applications program affect the numbers of graduate students entering technical fields?

To a significant extent, the answer depends upon how great the reductions are and how OSSA would distribute them across the programs. There are three components of the graduate student population to be considered. One consists of students funded directly by OSSA. Another consists of students who enter fields that deal with the "tools" used in OSSA projects, e.g., propulsion, structures, and power; electronics, including communications and information systems, etc. The third component consists of students who enter these fields as a consequence of having been inspired by some OSSA-funded project.

I do not have the data on the numbers of students funded directly by OSSA, but I believe NASA has them. An assessment of the effect on the other two components is of course more difficult. But the technical requirements of OSSA missions provide incentives for progress in many of these fields, and products of OSSA missions create interest that leads to studies in these fields.

Smaller Satellites

Dr. Coleman, you articulated the need for smaller satellites and the benefits they can generate both in our effort to attract more students to the sciences and to the space program as a whole.

- o Where would you draw the line in your effort to downsize spacecraft?

If the playing field were level, the only line I would draw is the one that separates the best way to do a job from the other ways to do the same job.

As I remarked in my testimony, the larger platforms have their place in a properly balanced program. They should probably be the major component.

But their place in the program is established. I am concerned about the component at the other end of the size range, the component that is essentially missing. In my opinion, it is essential that the smaller platforms be included in the tradeoff studies so that this line can be drawn as the result of appropriate cost-benefit considerations.

- o For example, NASA has justified both the EOS polar platforms on various scientific, engineering, and budgetary arguments, an approach which has tentatively been confirmed by the National Research Council. How do you respond to the justified need for such larger platforms?

As I commented previously, I am trying to keep separate the generic issue of low-cost access to space for small science and technology and the very timely and emotional issue of the particular baseline design for EOS.

That said, I believe that my colleagues who participated in the NRC study confirmed the need for simultaneous observations of a single footprint along a common line of sight. I believe they also accepted NASA's judgement that the EOS platforms as currently configured represented the best way to do this job.

NASA's approach may well be the best. However, as I understand it, the study participants did not undertake an independent examination of alternatives. My own view, based in part on a recent study by three other colleagues, is that these simultaneous measurements can be obtained with a cluster of smaller, but still rather large spacecraft and that this multiple-satellite approach has significant advantages cost, risk, and timing.

Senator GORE. How would you launch these? Pegasus?

Dr. COLEMAN. Pegasus is a good prospect. My understanding is that the cost of the aircraft is a potential problem. There is a debate going on about the relative cost of air launch and surface launch. So Pegasus could well be the right choice.

Senator GORE. What is their projected launch cost now?

Dr. COLEMAN. The numbers I hear have gone up about $1 million every two or three months. As I recall, it started at five, and the last number I have heard is eight to nine. These estimates depend upon numbers such as rates of cost amortization, so an accurate estimate is a tricky thing to come up with. But these high estimates indicate that, to a significant extent, we are still doing things the old way: Our quality assurance reliability, design, etc. There is a whole lot of stuff in these small launch vehicles and spacecraft that is ten year-old design, for the reasons that I outlined in my written testimony. We are just not getting the costs down the way we are going.

Senator GORE. Well, basically you are saying that in every aspect of the space program we need, in your opinion, to have more emphasis on small missions, small satellites launched by cheap and inexpensive, expendable launch vehicles?

Dr. COLEMAN. That is correct.

Senator GORE. And your basic logic is that gives a lot more flexibility to the program to respond to the best small missions that bubble up out of the peer review process?

Dr. COLEMAN. I think we can do a lot of jobs better, and I think we can also do the training of the experimentalists and engineers in space science and technology better. And I will tell you one thing I know. A program of this kind would be a lot more exciting. I mean, it is just what we need to get the young people into this business of science and technology.

Senator GORE. Well, again, I have read your complete statement, and I commend it enthusiastically to my colleagues. Sometimes we do not listen to the new ideas that challenge what the institutional thrust represents, and today we have had an opportunity to hear a new perspective.

Do either of you all—have you had a chance to look at Dr. Coleman's full statement?

Dr. MASON. Not the full statement.

Senator GORE. Do you know what his proposal is?

Dr. MASON. Yes, I do.

Senator GORE. Do you want to react?

Dr. MASON. Well, I am involved in one of the small explorer missions, and I can say he is absolutely correct. The missions at the present size are an excellent start, but they are still expensive enough so that there is very little tolerance for risk, (or tolerance for failure) and that means that they will be run and managed in an expensive fashion. And so until you have got the number of launches up, you have no chance of really bringing down the overall management and complexity of the mission.

Senator GORE. So there is a negative synergy between the complexity and the size of missions and the expense on risk management?

Dr. **Mason**. It is also involved with the numbers. it is the numbers as well. If you have a project that only does one mission every two years, the psychology is there. If you do 20 missions, you look at them quite differently, and so the numbers are as important as well.

Senator **Gore**. Dr. Dutton?

Dr. **Dutton**. When the Space Studies Board did the study on the earth explorers we were enthusiastic about some of the points that Dr. Coleman has made. One of the points that we looked at qualitatively rather than quantitatively was that one way to achieve the cost profiles that you want is to make the principal investigators responsible for some of these things rather than having an elaborate quality assurance control.

Senator **Gore**. And you cannot do that if you have everything on one big mission?

Dr. **Dutton**. No. It belongs to the PI. It is his or her problem.

Senator **Gore**. Then the costs are coming down?

Dr. **Dutton**. Item two, you do not try to go for 99.99 percent success with one vehicle. You try to maybe build three at 75 percent, and the way that works, then, out of three launches you will get what you want.

Senator **Gore**. Well, very interesting discussion. I really wish we had more time to explore it. We have a whole series of questions that if it will not be too much of a burden for you all to respond in writing.

If we tried to continue this hearing with this series of votes going on, I am afraid we would keep you here past dinnertime. I do not want to do that. My family wants me home for dinner, too. I do not know if I am going to be able to make it. I hope the votes do not go that long, but we will have to adjourn at this point. Please accept our thanks and our apologies for the truncated nature of your appearance here today. But your statements speak for themselves, and I think they have been excellent. We appreciate it very much. The hearing will stand adjourned.

[Whereupon, at 4:15 p.m., the committee adjourned, subject to the call of the Chair.]

COMMERCIAL SPACE PROGRAMS

TUESDAY, MAY 15, 1990

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:10 a.m., in room SR-253, Russell Senate Office Building, Hon. Albert Gore, Jr. (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. The subcommittee will come to order. I would like to begin our hearing by apologizing to our audience and our witnesses for the short delay in the start of our hearing. After our hearing had been scheduled late last week, the Majority Leader scheduled a cloture vote this morning on the AIDS care bill, and it became necessary for Committee members to be on the floor precisely at 10:00 a.m. to cast that important vote. So I apologize, but it was unavoidable and I am sure you understand.

Today, we are finishing up a series of hearings on NASA's fiscal year 1991 authorization bill. This morning we are going to be focusing on current Federal programs and policies designed to attract private sector investment and involvement in space. To help us evaluate the adequacy of these efforts, we are fortunate to have a number of distinguished witnesses from both the Federal Government and the commercial space industry.

In the last two years, two issues, two large issues, seem to have dominated discussions in Washington and in Congress —the trade deficit and the budget deficit. Both have a very direct and real bearing on the future economic and national security of this nation. And one of the points I hope will come out in our hearing this morning is that the commercialization of space is part of that larger debate—the same with semiconductors, supercomputers, high definition television and other high technology activities.

The marketplace of tomorrow will be increasingly dominated by high technology, and if we are to compete in the marketplace of tomorrow we have to have a stable, consistent, predictable, reliable policy. The U.S. Government has to become a reliable partner with industry if we are to be successful in stimulating our economy, reducing our deficit, and maintaining our market share.

To date progress in this regard has, unfortunately, not been very good. Several years ago the Reagan Administration initiated the commercialization of the domestic launch services industry. Federal support for U.S. launch manufacturers was eliminated entirely, and individual companies were told that they were free to compete.

The result is that our domestic commercial launch industry, which is still in its infancy and struggling to secure a share of the world market, has been forced to compete, against government-supported launch services offered by the Europeans, the Chinese, and now possibly the Soviets.

Many of us on this Subcommittee predicted it at the time. It should not have come as a surprise or mystery to anybody. It was just a fundamental flaw in the Administration's whole approach to it.

The commercialization of LANDSAT presents a similar story. Very simply, the current policy of relying exclusively on the marketplace to develop a satellite remote sensing industry has not worked to anyone's satisfaction—anyone's satisfaction. It has been a failure.

The question is, what approach will the Bush Administration take with respect to the commercialization of space. Will it use NASA and the Department of Transportation to encourage and support private sector involvement in space, or will it continue its predecessor's laissez faire adherence to the free market approach, even though there is not a free market?

It is time for a change. It is time to invigorate our efforts in Washington to expand private sector investment in space with a sensible policy, one that is attuned to the realities of the modern world. It is time for the Congress and the Administration to develop a partnership with industry to support private sector opportunities, to explore the unlimited market potential that space offers.

We are fortunate to have a number of distinguished witnesses at today's hearing to discuss the commercialization of space. I am sure we will benefit from their invaluable insight and experience on this issue. I want to offer a special welcome to Joe Pawlick, who will be appearing on our first panel. Joe is with us today representing the Space Institute at the University of Tennessee, one of NASA's centers for commercial space development and a place where they are doing exceptional work on emerging space propulsion technologies.

I want to welcome all of our witnesses on both panels. Without objection, we will hold the record open for any opening statements from my colleagues on the Committee.

Now, panel 1: first of all, James T. Rose, Assistant Administrator, Office of Commercial Programs, with NASA. James Rose is accompanied by Joe Pawlick, Program Manager for the Center for Advanced Space Propulsion at the University of Tennessee Space Institute. And our second witness is Mrs. Stephanie Lee-Miller, Director of the Office of Commercial Space Transportation with the Department of Transportation. Mrs. Lee-Miller, would you introduce your colleagues there?

Ms. LEE-MILLER. Yes. I have our Program Counsel, Gerald Maysarra, with me, and the Associate Director for the Licensing Division, Norm Bowles.

Senator GORE. Very good. Mr. Rose, we will start with you. Without objection, your prepared statement will be included in the record in full, and we would like to hear you present a summary of it, if you would, please. Please go ahead.

STATEMENT OF JAMES T. ROSE, ASSISTANT ADMINISTRATOR, OFFICE OF COMMERCIAL PROGRAMS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY JOSEPH F. PAWLICK, JR., PROGRAM MANAGER, CENTER FOR ADVANCED SPACE PROPULSION, UNIVERSITY OF TENNESSEE SPACE INSTITUTE

Mr. Rose. Thank you, Mr. Chairman. I am proud to be here today because I think I do represent two areas—the commercialization of space and the transfer of NASA-developed technologies. Both of these, I believe, will play a vital role in our competitive posture in the future relative to the Europeans and to the Asians.

I think commercializing space is a prudent strategy for this country, and I agree with you entirely that we must join forces, government and industry, if we are going to compete in this arena.

For true commercialization of space to expand beyond the current communications field, private markets and products must be developed in new areas of communications, remote sensing and microgravity. New growth in these fields will provide the private markets vital to a healthy and growing transportation and infrastructure industry.

Therefore, NASA's strategy is simple. First, we will assist the private sector in establishing the technology and development base that can lead to new products and markets and, second, help establish the infrastructure and transportation industry which can directly contribute to the creation of these product markets. As markets develop, so will the supporting commercial infrastructure and transportation.

Now we must constantly remember, however, in the government that it is the private sector that will commercialize space, not the government. Therefore, how we implement government help to the private sector is just as important as the help itself. It is part of our strategy to avoid as much direct government oversight, control and direction in cooperative efforts as possible, and allow industries to help themselves in as true a commercial fashion as possible.

If we are successful in what we have set out to do in the Commercial Space Office in NASA, the need for government support will fade away as we go from technology research to development, into revenue-generating applications. I want to briefly summarize for you what we are doing and some of our progress.

To help develop private markets, how do we get a wide segment of American industry looking at space as an opportunity? In other words, the non-aerospace world, how do you get the duPonts, the Dows, the Amocos, the Genentechs to look at space seriously as a place to do work or to derive products from research done in that environment?

We selected a mechanism we call the Centers for the Commercial Development of Space as the focus and the way to do this. These are consortia made up of industry, academic and government, working together in a focused way. The research being done at these centers is driven by their industry partners. It is a true way of saying let us get our academic community and our industries working together on specific areas of interest that could one day have commercial potential in high technology fields that we hold important.

So we asked the CCDSs, as we call them, two major functions—to leverage a broad industry base to develop product-oriented technologies, and to stimulate commercial cost-effective transportation and infrastructure that will develop in concert with these markets.

To do that we also established a management council made up of each one of the directors from these Centers. We meet quarterly and they are an integral part in the decisionmaking process. We do not make random decisions; we make decisions that involve the Centers and their industry partners in what needs to be done and where we need to go.

Are the Centers working? There are some 16 of them in different fields, like materials processing; 5 Centers are located in that field. We have 3 in biomedical activities. We have 2 in remote sensing. We have 2 in space power, 1 in space propulsion, and 2 in robotics and 1 in major structures. So there are 16 of them focused in specific areas of technology. They have 193 industries now working with them. Statistically we are getting a very good involvement of the industry in the United States.

Some 52 universities are also associated with these Centers. That means we are getting in specific applied areas of technology the best professors throughout the country joining into that particular Center and have become a party to it. So we believe we are getting the type of participation both in industry and in academia that is required.

Other forms of measuring progress. When we first established the original 5 Centers, NASA's contribution to those Centers for the basic research was 80 percent and industry's contribution was 20 percent. Today, for all 16 Centers, the industry is contributing 70 percent to the maintenance of the base technology and the Federal Government is putting in 30 percent. So we do have a large-scale industry involvement looking at the technologies that will lead, hopefully, to new and improved applications and products.

Some 18 patents have been approved, 41 are pending. 800 publications have come out of these Centers in referee journals and some 91 publications are in work. More important, some 5 spinoff companies have come about or are in progress of coming about to pick up the technologies and already begin to provide some type of commercial enterprise.

We have focused in on 61 major technology fields that have developed from the work these Centers have carried out in their laboratories and through their analytical and testing activities, and they say we believe space might have an improved factor in these technologies, and now we are developing the type of flight test program that will go forward in the next 5 years that will begin to mature these technologies to a point that the industry partners can look at it and say, yes, there is something to be done with this technology and we will move it into a development and on into an application.

The main thing we must realize in commercializing space, as we call it, we have got to be patient. We have got to have the technology underpinning. And if the technology underpinning has been developed with industry, then the likelihood of industry picking it up and moving it forward, we believe, is accelerated.

We think that through the 61 technologies we are going to see a significant number of industries beginning to take the next step. I think you will hear some of that from our next panel in a couple of areas of interest.

How do we make sure that we get the information we need for these industries in a timely manner? We have developed a flight test program that will carry out some nearly 300 flight tests in order to mature these technologies to a point that the industry can decide it has something to do.

We are going to conduct some 12 flight tests in the cargo bay of the orbiter. We are going to conduct some 90 using the mid-deck space in the Spacelab. And that is all of the allocated space that we have on the basic secondary space aboard the shuttle; therefore, we plan to lease a commercial augmentation, mid-deck augmentation module which we have just held a competition for that will provide additional space to carry out some 70 experiments, starting in 1992.

Probably more importantly, we are initiating a new small ELV orbital program that will be done totally commercially, with reentry capability so that we can carry out another 23 major flight test elements in this particular program. And we will continue our sounding rocket program, which we established a year and a half ago to carry out 34 flight tests.

Incidentally, we will be flying the Consort, the sounding rocket, again from White Sands tomorrow. It will be its third flight. It will have some 12 payloads provided by the Centers. Some 4 of our Centers are represented on that particular flight that will be carried out tomorrow.

We think it is important and let me just comment. I said one of the objectives of the Centers is to tie the infrastructure and transportation world commercially in. By having the Centers procure and develop the proper commercial infrastructure to do the sounding rockets and now the ELV programs, we are beginning to establish the necessary capability within the private sector themselves to do major launches of the future, and we think that this is going to begin to develop the type of capability we will need as these technologies move into application. We will be bringing the transportation and the infrastructure along with it.

Because we have reached the point of actually getting into space to do that segment—and when I say getting into space, we will be maturing those technologies for industry's evaluation and ultimate decisionmaking over the next 5 years. For instance, 3 technologies will mature in 1991, some 11 in 1992, some 15 in 1993. The whole smear of these things will be covered over a 5-year time period.

We will begin to see industry coming along and asking for further development programs. Therefore, in our budget this year we have this new line item called Transportation in order to lease a commercial mid-deck augmentation module for hands- on capability, the continuation of the sounding rocket program and the initiation of the new ELV program, in which Joe Pawlick is going to take the lead role with the Center at Tullahoma.

We need some stability in making sure we can carry out this flight test program. If we do not carry it out, our industry partners will leave us. The commercial space budget is made up 40 percent to support the basic elements of the Centers to get them ready for flight and to do the integration work necessary to fly them. 43 percent of the budget will go to supply the transportation necessary to carry out the flight program.

Some 11 percent is used in the NASA Centers themselves on things directly supporting the CCDS program. And 6 percent is for the handling of the program from the things we have to do here in Washington. I call that the overhead, if you want to say that.

But all of our budget basically goes to this program, to the industries working and to the Centers working to make it happen. Because we leverage heavily, most of the Centers are now paying $3 to $1 that we contribute, you cannot afford stretchouts and things because you lose a lot and you are going to lose their support. So from that point of view, we need our budget and we need it to keep the momentum going in the program that we have now established.

Before I turn it over to Joe to talk about the CCDS, I want to briefly mention our technology utilization program. As you know, we are the one agency that has had an active technology transfer program for the last 30 years. We think over that time period it is estimated that some 30,000 applications have been derived from NASA-developed technology. Recently we completed a review of some 259 companies that we know had used space technology to spinoff activities. We went to some 500. 259 agreed to actually provide information, detailed information, from their books and what have you.

Of the 259, they say that it is estimated that $21.3 billion in revenue from sales or new and improved products have resulted in the time frame since they went into business. Some $316 million has also resulted in savings. They have paid some $356 million in income tax and they estimated they have created some 352,000 jobs in that time frame. That is a sampling of what space technology has contributed.

We continue to think we can provide a leadership role in space transfer. We have a network system set up for disseminating information on the technologies that we are developing. We are now establishing repositories through the National Technology Transfer Center and AdaNET software repositories of activities that will be national in scope that will support all of the government laboratories in West Virginia.

No matter how good we think our program is, we can always do better. I think we can do better than just doing level of effort space transfer of the technology. I think we can optimize that system. I think we have a data base that we can do to say we are doing the most optimum job you can do for the amount of research that we are carrying out, and we tend to want to have that done before the summer is out to see what that means.

Also, my office carries out the Small Business Innovation Research Program, and the results of that program, we like it. NASA is very happy with it. All of our Center directors have nothing but compliments for it. And it is one of those areas that I think some people went into with skepticism and it is working.

Senator **Gore**. As the author of that program, I am real glad to hear your comments on that.

Mr. **Rose**. There are two issues that I want to bring to your attention. One is that, you know, there is a sunset date in 1993, and if we are to plan for a sunset date we almost have to do it starting this fall, because of the length of time to go from a phase 1 program through a phase 2. It takes about 3 years.

So I urge the Congress to take action on this thing as soon as you possibly can to determine whether we will continue it or not.

The second issue is that last year the Senate authorization committee, recognizing how big the NASA program is growing and the amount of scope that it takes to administer such a program, our lawyers are convinced that the setaside money of 1-1/4 percent can only be used for the small businesses. You recognized that and decided to allow us to use 5 percent, and that was in your bill last year, to administer this program.

We think that is vital to a healthy and a growing, successful program. We request that type of support again this year, if it is possible.

I think I have said enough. I am going to let Mr. Joe Pawlick talk, if you will, and let him explain some of the things that the CCDSs are doing, his Center in particular, and how he in Tennessee plans to help us develop the commercial infrastructure element of a new ELV program.

[The statement and questions and answers follow:]

Statement of

James T. Rose
Assistant Administrator
Office of Commercial Programs
National Aeronautics and Space Administration

before the

Subcommittee on Science, Technology and Space
Committee on Commerce, Science, and Transportation
United States Senate

Mr. Chairman and Distinguished Members of the Subcommittee:

There is increasing recognition, both in the U.S. and abroad, that space has attributes that are of great value. These resources and characteristics will play a major role in opening a new economic frontier for the spacefaring nations of the world.

It is clear that commercial development is both a logical progression in America's civil space efforts and a prudent competitive strategy. NASA's Office of Commercial Programs (OCP) is the focal point for the agency's efforts to stimulate and assist expanded involvement and investment by the U.S. private sector in civil space activities. OCP also helps bring about the commercial application of space technology.

The past year was exciting for OCP's commercial development program. We witnessed the first federally licensed commercial launch, the first corporation formed as a direct result of work done in cooperation with a NASA Center for the Commercial Development of Space (CCDS), and the first technology spinoff from a CCDS. I am pleased to have the opportunity to discuss these important programs. I will begin with a description of our efforts to encourage and support the commercial development of space.

COMMERCIAL DEVELOPMENT OF SPACE

True commercial space is achieved when industries are established that generate new products and services for private markets. Development of these new products and services will, in turn, support the growth of other commercial space industries, such as transportation and infrastructure.

Our challenge is to conduct a program that helps industries develop commercial space markets, and cost-effective commercial space transportation systems and infrastructure. We believe that we have been successful in structuring a comprehensive and aggressive program which meets this challenge. It is a bounded program, not just a level of effort. The activities of this program will lead to the creation of new products and services, leading to new markets and businesses. These, in turn, will drive the need for new cost-effective commercial space transportation and infrastructure.

1. Involving Industry in Planning for Office of Commercial Programs Activities. Since commercial development of space will ultimately be done by the private sector, we have sought and obtained significant industry advice and support in planning and developing our program.

a. Commercial Programs Advisory Committee (CPAC). One of NASA's goals is to help the private sector develop commercial space as a new sector of the national economy. CPAC was established in FY 1989 as a standing committee of the NASA Advisory Council. Unlike ad hoc committees, CPAC is able to provide NASA with continuing advice on the proper roles and responsibilities of government and industry in the commercial development of space. CPAC is composed of corporate Chief Executive Officers, university presidents, and is chaired by Mr. Edward Donley, Chairman of the Executive Committee, Air Products and Chemicals, Incorporated.

In 1989, CPAC published its report, ***Charting the Course: U.S. Space Enterprise and Space Industrial Competitiveness***, which summarizes the results of its first year of work. It proposes nine key recommendations that executive branch leaders, government agencies, and the Congress can implement to foster

U.S. space enterprise and space industrial development. NASA is currently reviewing these recommendations to determine appropriate action.

b. Strategic Planning. In FY 1988, NASA requested the American Institute of Aeronautics and Astronautics (AIAA) to conduct a study of issues and potential objectives associated with commercial development of space. AIAA formed a steering committee consisting of senior-level, private sector managers with considerable experience in the commercial space environment. The resulting study document, "Issues in Strategic Planning for Commercial Space Growth," represents inputs from more than 90 industry representatives, and is being used to support OCP strategic plan development.

c. Infrastructure Policy. Based on industry input, NASA has also refined the criteria and guidelines used for evaluating the infrastructure proposals coming from the private sector. Establishing appropriate criteria and developing appropriate processes are both necessary to increase NASA's planning capability and to heighten the potential for success of the proposed ventures.

2. Supporting the Development of New Industries. True commerce, the buying and selling of commodities, is characterized by the private sector developing new products and services for private sector markets. A sound technology base is the fundamental element upon which these markets, and ultimately, industries are built. These new markets, in turn, will build a demand for new cost-efficient space transportation and infrastructure. However, new markets will not emerge overnight. They must be carefully nurtured. Our program is targeted toward helping industry overcome obstacles to entering these new markets. Two elements of this program are the CCDS Program and partnerships with U.S. industry through cooperative agreements.

a. The CCDS Program. NASA's 16 CCDS's are competitively selected consortia of universities, industries, and government involved in early research and testing phases of potentially commercially viable technologies. The CCDS's play a vital role in developing a technology base upon which to build new commercial space industries. The CCDS Program helps move emerging technologies from the laboratory to the market place with speed and efficiency by leveraging a broad industry base to develop product-oriented technologies and stimulating commercial cost-effective transportation and infrastructure ventures.

(1) Leveraging a Broad Industry Base to Develop Product-oriented Technologies. The 16 CCDS's involve the active participation of 52 universities and 175 companies. Industry has proven its commitment by investing heavily in this cooperative program. For example, the average ratio of industry matching funds (measured in cash and in-kind services) to government funding for the 16 CCDS's, is approximately 2.2 to 1. The ratio of just the first five CCDS's, established by NASA in 1985, has risen to 3.4 to 1.

Sixty-one new technologies are currently defined by the CCDS's. Extensive ground tests have proven the need for flight testing of these technologies in the space environment. Each technology will require a specific number of flight tests to mature it to the point that a decision can be made regarding the viability of commercial applications.

The CCDS Program establishes a technology base for the 61 identified technologies by 1995. The process is an interactive one, with industry determining potential applications throughout the entire time. We believe that with the current efforts, the maturation of these technologies will occur between 1990 and 1995. We have identified 1 that will mature by the end of 1990, 2 by the end of 1991, 11 during 1992, 17 in 1993, 11 in 1994, and 19 in 1995.

Maturing these technologies through a flight test program requires access to space. OCP has conducted a "bottoms-up" analysis to determine transportation requirements. As of May 1, 1990, 277 payload flight tests are planned through 1995, 12 of which will be carried out in the Space Shuttle cargo bay and 90 in the middeck/Spacelab. Seventy will be accommodated using a commercial payload module, 23 are scheduled for flights aboard expendable launch vehicles (ELV), 34 on sounding rockets, and 48 will fly using "GetAway Specials (GAS)" type hardware in the Space Shuttle payload bay. A significant portion of our budget request for FY 1991 is for obtaining space transportation. This will be discussed in more detail in Section 3., FY 1991 Commercial Use of Space Budget Request.

Since the inception of CCDS's, the following experiments have been completed toward technology development: 935 drop tube/drop tower experiments; 12 Lear/KC-135 flights; 18 payload flight tests aboard 2 sounding rockets; and 9 flight tests aboard the Space Shuttle. Through these experiments, industrial researchers obtained invaluable data which contributed to decisions as to whether or not further flight tests are warranted.

The Center for Macromolecular Crystallography, University of Alabama-Birmingham, and industrial researchers has had experiments performed aboard the Space Shuttle launches STS-29 and -32 that, coupled with its 1988 experiments aboard STS-26, could lead to commercial in-space production of tiny protein crystals. High quality crystals have been obtained from the protein and enzyme samples flown, providing knowledge regarding the samples. Four of the samples grew crystals of exceptional size and quality. Protein crystals are tools for scientists who are working to develop powerful new drugs to combat cancer, high blood pressure, organ transplant rejection, rheumatoid arthritis, and many other diseases. Payloads from the Center for Advanced Materials at the Battelle Laboratories, the Center for Bioserve Space Technologies at the University of Colorado, and the Center for Cell Research at Pennsylvania State University are also scheduled for flights this year.

Two CCDS payloads were carried on the recent flight of STS-31, along with the Hubble Space Telescope. A fourth Protein Crystal Growth payload from the Center for Macromolecular Crystallography, University of Alabama-Birmingham, resulted in more high-quality crystals, including some of the largest ever grown. The Center for Advanced Materials at the Battelle Columbus laboratories also flew their first Space Shuttle payload. Their investigations into Polymer Membrane Processing were successful, producing well-ordered porous thin-film membranes with significant structural differences from similar materials produced on Earth.

The technologies under development at CCDS's are recognized as "new" by the industrial space community. Eighteen technologies have been patented, while 41 more are awaiting confirmation. CCDS's have also generated close to 800 technical publications in refereed journals, with 91 more in work.

A significant milestone was reached this year with the first CCDS technology spinoff. A collaborative effort between the Center for Commercial Development of Space Power (Auburn University) and Maxwell Laboratories has resulted in a stronger, more efficient power supply applicable to laser work now being marketed by Maxwell. While conducting research into space power equipment, potential commercial applications to existing terrestrial markets have been identified. There are other efforts in process at the Center for Mapping (Ohio State University) potentially to spin off other technologies.

BioCryst, a Birmingham, Alabama, pharmaceutical company, was incorporated January 1, 1989, as the first corporate spinoff resulting from CCDS involvement. Their work was done in cooperation with the Center for Macromolecular Crystallography, University of Alabama-Birmingham. BioCryst was formed to apply the tools of X-ray crystallography and computerized molecular modelling to the development of new pharmaceutical compounds. BioCryst has already applied for patents for its work on anticancer drugs. Other groups are currently working to spin off two more companies.

(2) Stimulating Commercial Cost-effective Transportation and Infrastructure Ventures. On March 29, 1989, the CCDS for Space Materials Development at Huntsville, Alabama, successfully launched six CCDS-developed payloads on a commercially provided launcher, Starfire, at a cost of approximately $1.4 million. The cost included both the launch vehicle, launch and recovery system, and payload integration. Eight members of U.S. industry (two of which were start-up space companies), two other CCDS's, and three other universities were involved in the project. The suborbital flight, named Consort 1, provided 7 minutes of microgravity. The entire effort to integrate the payloads and commercially procure the launch services, and launch and recover the payloads took only 9 months, compared to the traditional

18-24 months. It demonstrated that academia and industry can move quickly to develop commercial opportunities for space research in a highly efficient and successful manner, with minimum government involvement.

A second commercial launch, the Consort 2, experienced a second-stage guidance failure within seconds after lift-off on November 15, 1989. Safety personnel were forced to destroy the booster, but the payload module was parachuted to safety. The payload was recovered undamaged and is being prepared to fly again in May 1990.

The next series of flights will occur in the late fall of 1990 aboard the Joust-1 vehicle. The more powerful Joust-1 will provide from 12-16 minutes of microgravity depending upon the payload mass as opposed the 6-8 minutes provided by the Consort depending its payload mass.

CCDS's are also planning and initiating a variety of hardware development projects to provide CCDS researchers with cost effective means of conducting experiments in space. One such project, in its second year of development by the Space Vacuum Epitaxy Center at the University of Houston, is a "wake shield" facility for space vacuum epitaxy research.

The Wake Shield Facility will provide a high ultrapure vacuum by pushing aside stray atoms and molecules found in low Earth orbit. Researchers can use this high vacuum with near infinite pumping speeds to grow thin films with hundreds of layers that are each only a few atoms thick. Such multilayered thin films can be used in opto-electronics, microwave amplifiers, and various electronic applications.

Comparative studies indicate that the estimated costs and time period for developing the Wake Shield Facility through commercial practices will be significantly less than for NASA to contract to build the facility itself. More importantly, purchasing the facility from commercial sources will also help to stimulate the growth of a private sector capability to manufacture commercially oriented space flight hardware. The facility is currently scheduled to fly in early 1992.

(3) Creating a Planning Function for Future Industry Needs and Requirements. OCP has initiated an activity, led by the Battelle CCDS, to work with the private sector in the development of space industries, particularly in the areas of transportation and infrastructure. Through the existing CCDS's, we have gained the active participation of the private sector in building the technology base essential to the commercial development of space. But this technology base does not address the issue of what transportation and infrastructure elements will be important to support the new space industries as they develop and mature. The industry development activity will address these specific issues.

The Battelle CCDS is taking the lead in this activity. Battelle will work, both with the other CCDS's and with private sector companies directly, in identifying critical elements that must be in place in order to support the growing needs of successful private sector ventures. The ongoing recommendations resulting from this effort will assist the private sector in meeting its infrastructure and transportation needs.

By using the established CCDS structure, we will be facilitating the planning by industry for its own needs. It is vital, as part of our program, that we not only receive the input of industry in planning for the near-term, but also for the mid- and far-term.

b. Cooperative Agreements

(1) Description of the Program. NASA has developed a significant number of innovative working agreements to minimize business risks and give private firms access to our facilities and other capabilities. These agreements are each designed to meet requirements of different commercial ventures. The Joint Endeavor Agreement (JEA) and other types of agreements between NASA and the private sector are the instruments through which we attempt to mitigate the private sector's extraordinary up-front technical and financial risks associated with these capital investment projects. For example, under a JEA, the private sector partner funds experiments and the government provides the transportation and other services. Another innovative

agreement is the Space Systems Development Agreement which can have deferred payment financing arrangements. NASA also enters into agreements to provide assistance, services, and facilities in support of the development of a commercial ELV industry.

(2) FY 1989 Cooperative Agreements Accomplishments. In FY 1989, NASA expanded its partnerships with U.S. industry through the signing of cooperative agreements providing support for industrial space research, commercial space transportation, and the private development of space infrastructure and services.

(a) Corabi International Telemetrics, Incorporated, signed a Memorandum of Understanding (MOU) supporting the commercial development of telemedicine services for the Space Station Freedom.

(b) Coca-Cola Company signed an MOU in support of the firm's investigation of fluid dynamics, gas-liquid separation, and metering technologies in space.

(c) In June 1988, NASA published through the ***Commerce Business Daily*** an Announcement of Opportunity for academia or industry to present proposals for the commercial development of expended Space Shuttle external tanks in suborbital or orbital flights. Two firms were selected in FY 1989 for further discussions: Global Outpost, Incorporated, and the University Corporation for Atmospheric Research. Each firm has independently negotiated a cooperative agreement with NASA which, if technical, safety and business criteria are met, would result in follow-on launch service agreements with the agency for up to five expended Space Shuttle tanks.

(d) In the past 4 years, NASA has signed a number of support agreements with commercial ELV firms to help foster a robust U.S. industry. The first NASA support agreement was with Space Services, Incorporated, signed September 4, 1986. A support agreement with General Dynamics was signed in September 1988. During FY 1989, agreements were signed with LTV Missiles and Electronics Group; Martin Marietta Commercial Titan, Incorporated; and

Conatec, Incorporated. NASA continues to support commercial ELV launch activity as evidenced by the agency's discussions with firms new to the field of commercial expendable launches.

In FY 1989, discussions were also held with several companies which may lead to cooperative agreements in the future. Two examples are: (1) Unocal (Union Oil of California), which is already engaged in a commercial remote sensing project under a Proprietary Work Agreement with the NASA John C. Stennis Space Center (SSC); and (2) Genentech (a biotechnology firm), working with the Center for Cell Research (Pennsylvania State University), signed a Technical Exchange Agreement with the NASA Ames Research Center and is discussing other possible cooperation.

3. FY 1991 Commercial Use of Space Budget Request. The Commercial Use of Space Program depends on the strategy of leveraging government and industry funds. In the CCDS Program, for example, industry is putting in approximately $2.2 for every $1 that the government contributes. Therefore, any funding reduction from NASA's budget request represents a significant potential loss in industry investment.

NASA traditionally responds to funding or scheduling problems by stretching out the work over a longer period of time. NASA's contractors will stretch their programs accordingly. However, when operating in a leveraged program arrangement, as OCP is, we run a high risk of losing significant amounts of participation and support. Therefore, keeping commitments, not only in budgets, but also in schedules, is essential for carrying out the type of program OCP has established.

For our Program to succeed, we must demonstrate our commitment and continuing support by providing firm flight opportunities. We have mapped out a detailed flight program for these commercial payloads and determined that standard Space Shuttle flights, including opportunities in the middeck and the cargo bay, are not sufficient to meet industry's needs. To help fulfill these requirements, we have initiated efforts to promote the development of alternate means of transportation. ELV's, including sounding rockets, commercial middeck augmentation, along with other commercial payload carriers are required and are included in our budget request of $33.5 million for Commercial Transportation.

In addition to providing transportation for planned CCDS and JEA payloads, the OCP budget request of $76.6 million for FY 1991 Commercial Use of Space will also be used to carry out the following:

a. In Commercial Applications, $38.9 million to include:

(1) Continuing grants to 16 CCDS's,

(2) Providing augmentation which include support in developing research equipment and flight experimentation hardware,

(3) Providing analytical and physical integration required for Space Shuttle payloads flown under JEA's, and

(4) Supporting NASA field installation projects including the Earth Observation Commercial Applications Program at SSC; an improved materials processing in space container at NASA George C. Marshall Space Flight Center; and a materials processing robotic demonstration at Goddard Space Flight Center.

b. In Commercial Development Support, $4.2 million to include:

(1) Studies in international competitiveness,
(2) Economic analysis studies,
(3) Strategic planning,
(4) Support for CPAC, and
(5) Headquarters contractor support:
  - Space Station Freedom requirements
  - Pricing studies
  - Automated data processing support

The required funds can be viewed as a strategic investment in what promises to be an exciting new element of our economy, and a factor in U.S. competitiveness.

TECHNOLOGY UTILIZATION

NASA also fosters commercial interest in space by accelerating transfer and use of NASA-generated technology to private industry. The technology which NASA develops to meet its research and program goals represents an important national resource. The NASA Technology Utilization Program spreads this valuable technology throughout the economy by working with U.S. industry to adapt space technology to meet its needs.

NASA, through this long-standing program, has maintained a systematic approach for identifying space technologies which may have useful application in the nonspace sector of the economy.

Our Technology Utilization Program involves both technology dissemination and technology application. Technology dissemination requires the identification and gathering of information on aerospace technologies making this information available to the private sector. Technology application is the use of these NASA technologies in specific projects for public benefit.

1. Technology Dissemination

a. Industrial Applications Centers (IAC). NASA's network of 10 IAC's is the key component of the technology utilization information dissemination system. Their computerized access to technical information has stimulated significant corporate interest in government-funded or -derived advanced technologies.

IAC's cultivate strong ties with industry, identify industrial client problems and technological interests, and assist their clients through exchange of technological information. IAC's are backed by a score of IAC Affiliates, state-sponsored business and technical assistance centers, that provide access to the technology transfer network. The network now resides in 41 of the 50 states.

b. Computer Management Software and Information Center (COSMIC). In addition to technology, NASA also has developed many types of computer programs which constitute a valuable resource available for reuse. Much of this software is directly applicable to secondary applications and can be adapted to special purposes with little or no modification.

COSMIC is NASA's mechanism for making such programs available to the private sector. COSMIC customers can purchase a program for a fraction of its original cost and get a return many times the investment, even when the cost of adapting the program to a new use is included.

c. AdaNET Software Repository. The AdaNET Software Repository is intended to be a self-supporting commercial organization to provide users of Ada with information sharing and depository services. The objectives of the program are to re-automate the U.S. industrial base; provide an automated, on-line clearinghouse for Ada software; and to provide a reusable Ada software inventory from NASA, Department of Defense, and other resources.

An analysis of Ada user requirements and acquisition of initial Ada library software modules has been completed. We have now entered Phase II of the implementation plan. In Phase II, MountainNET, Incorporated, will, among other tasks, prepare a plan to expand the current University of Houston, Clear Lake, software engineering and Ada data base and incrementally add commercialization support services.

d. National Technology Transfer Center (NTTC). The mission of NTTC is to enhance the United States' competitive posture by facilitating the transfer of federally sponsored research and development (R&D) to the private sector. This will be accomplished by providing a nationwide focal point for technology transfer activities, technology and network assistance, linkages to investment and business development sources; and a national forum for developing technology transfer requirements. NTTC will assess the relevance of technology to industry needs and will provide private sector users effective access to appropriate and relevant technology transfer resources.

A planning and development grant was awarded to Wheeling College, located in West Virginia, on March 1, 1990. The 8-month planning effort will focus on identifying NTTC operational requirements and resource needs. The initial development phase is scheduled to start in July 1990 through a cooperative agreement arrangement.

e. Publications

(1) The publication of ***Tech Briefs*** is a major element of the technology dissemination program in OCP. This document provides information on NASA research innovations and is distributed monthly to approximately 200,000 members of the U.S. industrial community.

(2) NASA's annual ***Spinoff*** magazine is intended to heighten awareness among potential users of the NASA-developed technology and the economic and social benefit that might be realized by secondary applications. It describes mainline NASA efforts in major programs that generate new technology and the mechanisms NASA employs to stimulate technology development. Examples of spinoff products in the areas of public safety, the environment, medicine, consumer/home/recreation, computer technology, and industrial productivity are found in ***Spinoff 1989***.

2. Significant FY 1989 Technology Dissemination Accomplishments. A recently completed study to assess the economic impacts of NASA technology transfer activities indicated substantial financial benefits to U.S. businesses. The research determined the estimated revenues and cost-savings derived from a sample of applications reported in NASA's ***Spinoff*** publication.

The study, entitled, ***An Exploration of Benefits from NASA "Spinoff,"*** traced more than 400 applications reported in the magazine between 1978 and 1986. It was found that 342 applications resulted in acknowledged contributions to sales or savings. Of these, about 75 percent, or 259 cases, permitted some quantification of sales or savings. The 259 applications in industry were determined to have contributed to the sales of new or improved products in the amount of $21.3 billion and contributed to savings of nearly $316 million.

It was also calculated that the revenues produced through the estimated sales generated federal income tax revenues of nearly $356 million. Additionally, 352,000 jobs were projected to have been created, or retained due to the increased revenues (not savings) attributed to these spinoffs. This study identifies continuing social and economic benefits generated by NASA's technology transfer activities.

3. Technology Application. Technology application is accomplished through interaction with public and private sectors of the economy to identify specific needs or problems and provide potential solutions through aerospace-developed technologies. Currently, there are 73 joint-sponsored application projects underway at the 9 NASA field installations.

Examples of FY 1990 and FY 1991 technology projects include:

a. Orange, polarizing sunglasses, marketed worldwide, that improve visual acuity and protects the eye from the two most common causes of blindness in the Western World. The original technology resulted from research into the simulation of sunlight and the protection of the human eye in space. This technology has significantly impacted the sunglass industry.

b. Micro Climate personal cooling system (cool suit) for people in occupations where elevated body temperatures can cause fatigue and collapse. Applications from this Moonsuit technology continue to increase and include protection of public service and industrial firefighters, hazardous materials controllers, and for workers in such industries as nuclear power, glass manufacturing, and chemical processing. Another use of this technology application has greatly increased the quality of life for children and other individuals suffering from hypohydrotic ectodermal dysplasia, a disease which eliminates the body's capability of perspiring.

c. A line of contamination control garments used by hospitals, pharmaceutical and medical equipment manufacturers, aerospace and electronic plants, and other industrial facilities where extreme cleanliness is important. The garments, based on NASA contamination control technology, are disposable, which eliminates the costs of laundering and repair, and come in sterile and nonsterile forms.

Many hundreds of major and minor techniques and products developed for the space program have valuable secondary applications. Over the years, NASA's transfer of technology to the private sector has resulted in over 30,000 spin-offs and applications which have resulted in new products, companies, and industries.

4. Significant FY 1990 Technology Applications Accomplishments:

a. Stirling Engine. In response to congressional interest, NASA initiated a study in October 1989 to determine whether the Stirling engine technology could be a long-term solution to the Nation's automotive emission problem. The study also addressed whether a commercial demonstration is the logical next step; the optimal federal agency long-term sponsor; the distribution of private (and public) financial contributions; and, mechanisms for securing funds. The Departments of Army, Air Force, Energy, and Transportation, and the Environmental Protection Agency participated in the study.

The study is now complete and concludes that while the Mod II ASE has demonstrated multifuel operation and good driveability, it has failed to demonstrate the fuel economy or emissions goals of the Department of Energy ASE Program. In addition, the study presents the following findings:

(1) The Mod II ASE has not achieved a level of performance or value that would interest any federal agencies or engine/automobile manufacturers in a commercial demonstration program.

(2) Introducing any new alternative engine directly into the automobile in the near-term is highly unlikely because of the large capital investment, the high risk, and the difficulty of predicting manufacturing costs.

(3) Advancing the program beyond the proof-of-concept phase must involve both the engine manufacturer and the vehicle manufacturer.

(4) Commercial demonstration plans must be defined primarily by the engine manufacturer and developer, and the user organizations.

b. Spinoff Hall of Fame Inductees. In April 1990, the U.S. Space Foundation honored two technology spinoffs that resulted directly from earlier NASA programs. The organization hosted a special ceremony at its headquarters in Colorado Springs, Colorado, to recognize the individuals and organizations instrumental in adapting the technology for commercial applications. Two technologies were inducted into the U.S. Space Foundation's Spinoff Hall of Fame and represent but a few of the thousands of technology applications spun off from NASA's R&D programs. The two technologies are:

(1) Heat pipe technology developed from NASA's concern with temperature control in nonrotating satellites. Applications include protection of the Alaska Pipe Line and many other energy conservation devices.

(2) Safety grooving developed by NASA to prevent aircraft tire hydroplaning on the runway. The grooving technology is used to improve the safety of commercial runways, interstate highway curves and overpasses, pedestrian walkways, and many other slippery-when-wet surface problems.

I am proud that we are continuing progress in the implementation of recent congressional and executive actions aimed at accelerating the transfer of federally funded technology into the private sector. NASA's well-developed program is serving as a model for other agencies as efforts to assist U.S. industrial competitiveness intensify.

5. FY 1991 Technology Utilization Budget Request. In FY 1991, the budget request for the Technology Utilization Program is $24.4 million. These monies will be used to accomplish the following activities:

a. Promote awareness of NASA's Technology Utilization Program and resources available to the public and private sectors;

b. Complete implementation of the AdaNET Program and Phase I of an NTTC Plan;

c. Continued maintenance of the IAC network and its installations to provide for expanded identification of NASA technical capabilities and expertise;

d. Broaden application team responsibilities to assist IAC's in bringing together industrial client problems with existing aerospace technologies; and

e. Improve the capability of the technology utilization offices at the NASA field installations to increase the level of technology transfer activities.

SMALL BUSINESS INNOVATION RESEARCH (SBIR)

While not directly included in this budget request, OCP has management responsibility for the SBIR Program. I would like to take this opportunity to discuss this Program which plays an important role in OCP's commercial development program. SBIR Program objectives, established by law, include stimulating technological innovation in the private sector, strengthening the role of small businesses in federal R&D programs, fostering and encouraging greater participation of minority and disadvantaged persons in technological innovation, and increasing private sector commercial development of innovations derived from federal R&D.

Participating agencies support the SBIR objectives by reserving a statutory percentage (1.25) of their extramural R&D budgets. This reserve is awarded to small business concerns for R&D during the first two phases of a uniform, three-phase process. During FY 1989, the SBIR Program received a substantial increase as part of the overall increase in NASA's R&D funding. This, along with an active outreach program, resulted in an increase in the number of high quality proposals submitted by small, high-technology businesses.

Since the inception of the Program in 1983, NASA has awarded 1,243 Phase I contracts (including 251 during 1989) to determine the feasibility of innovative concepts proposed by small business. The 251 Phase I awards made in 1989 were selected from more than 2,140 Phase I proposals received in response to our 1989 Program Solicitation. Of the nearly 1,000 Phase I projects in our Program which have been completed to date, 510 have been selected for further development under Phase II contracts. The 100 Phase II selections made in 1989 were for continuations of Phase I projects completed in 1988.

The initial assessment of SBIR Program accomplishments, conducted more than a year ago, indicated that all SBIR objectives were being achieved and that the Program had become a highly regarded element of NASA's overall R&D activities. The results of that assessment, with which the General Accounting Office concurred in their report to the Congress, indicated that the quality of research conducted in SBIR projects was as high as or higher than comparable research funded through other R&D means, and that more than half of the projects that had been completed were already incorporated or were planned for incorporation into NASA mission programs. Many projects had substantially advanced the technology base in several areas. Our assessment also found that at least one-fourth of the completed projects had resulted in early commercial products or enterprises by the small businesses. It was also found that a substantial number of minority and disadvantaged firms had won SBIR contracts for high-technology projects. Our ongoing assessment of the SBIR Program indicates that all those objectives continue to be met as the program grows.

Commercialization of the research results by small businesses, which is an important SBIR objective, continues to develop. Two examples noted here promise extensive commercial applications. One of these involves a solid-state laser source of ultra-narrow line width, frequency-stable laser light that NASA is carrying forward into the development of a laser communications module for use in space. Lightwave Electronics Corporation, of Mountain View, California, the small business conducting the research under SBIR, has successfully applied the technology in developing commercially available products for a variety of applications with sales of about 400 units so far.

A second example is the Photosyntheses Profiler being marketed by Biospherical Instruments, Incorporated, of San Diego, California. This device is an instrument developed for NASA to measure the variation of photosynthesis with depth in the ocean. Data needed to understand the initial steps in the food chain, including a joint U.S./U.S.S.R. oceanographic voyage to the Indian Ocean is provided. Diverse commercial applications now include assessment of fisheries and monitoring of municipal water treatment plants and reservoirs.

SBIR outreach activities by NASA in 1989 included participation in more than a dozen conferences and seminars aimed at assisting small businesses in understanding the NASA SBIR Program. In an effort to anticipate and encourage winning companies to develop the commercial potential of SBIR results, the SBIR Office has initiated a program to follow and report on projects as they proceed. Other efforts have centered on strengthening ties with NASA's network of IAC's and CCDS's to foster technology transfer and commercial application of NASA technology.

In addition, resource information documents are being made available, including a composite list of all NASA SBIR awards made to date and abstracts of all projects. These will be useful to small businesses interested in participating in the Program and to other firms interested in funding promising developments or in utilizing the results of SBIR projects through licensing, buy-outs, collaboration, consulting, or subcontracting.

Despite the indicated success and value of the SBIR Program, it should be noted that, unless it is reauthorized, the Program will come to an end on October 1, 1993, the "sunset date" specified by current legislation. Because of the sequential nature and timing of Phases I and II, an orderly phase-down of the Program requires 3 years. If the Program is not reauthorized, the NASA SBIR phase-down should commence at the time the Phase I award selections are made during October this year. As a result, a significantly smaller number of Phase I awards would be made this year than would otherwise be possible based on the increase in the SBIR R&D set-aside from the NASA R&D budget.

SUMMARY AND CONCLUSION

Industry's activities in commercial space have increased steadily and so have the successes. Procuring and launching a commercial sounding rocket, incorporating a company based on CCDS cooperation, and spinning off a technology for a company's use for profit are inspiring events of FY 1989 that encourage us to continue in our efforts to support industry.

The sales figures and tax revenues found in the study on technology utilization can only underscore the importance of that program as well. We can see that the private sector is eager to receive technology from NASA and can clearly put it to good use for the public good as well as profit generation, which, in turn, generates more taxable income.

The program that is underway in OCP is a well-defined effort on behalf of NASA to encourage industry investment in commercial space. The FY 1991 budget request reflects the need for increased program funding due to the increase in activity in cooperation with industry resulting from FY 1989 and FY 1990 successes. The rewards of these successes will be significant contributions to America's future industrial competitiveness, and provide important economic returns to American taxpayers.

NASA actively supports this Subcommittee's and the Nation's commitment to the commercial development of space. The commercial development of space program has specific objectives for capturing the drive and creativity of the private sector, for increasing NASA's effectiveness in conducting business with industrial firms, and impacting the competitive commercial space market. The partnership between government, industry, and the university community has allowed each to do what it does best. We believe that our approach is comprehensive, vigorous, and forward-looking; and provides the type of organization and structure needed to bring industry into the mainstream of space activities.

Responses to written questions submitted by Sen. Inouye resulting from the May 15, 1990, hearing.

Question 1: Is it still true that Japan can only launch from their launch site during two 45-day periods per year? I believe that NASA officials testified to that effect in May of 1989. Aren't Japanese investments in a facility they can only use twice a year a rather poor use of their funds? Are the Japanese investigating other launch facilities?

Answer 1: Yes, it is still true that the Japanese can only launch during two 45-day periods from southern Japan. They must work around the restraints of a strong fishing lobby in Japan. There have been some proposals for other launch facilities, but we have no indication that the Japanese government is planning to develop any new launch facilities at this time.

Question 2: The Japanese strength is in communications equipment for ground stations, is it not? Last year NASA officials said Japan had captured a majority of this market. Does this remain true?

Answer 2: This is still true. The Japanese strength is in communications equipment for ground stations, and they have captured a majority of the market.

Question 3: Do you know if Taiwan is also considering building a launch facility? If they are, can you estimate what it would cost them? Where would it be located?

Answer 3: NASA has not had any exchange with Taiwan regarding plans for a launch facility. The American Institute in Taiwan or the Taiwan Coordination Office at the Department of State may have more information.

Question 4: Are there any other Pacific Rim countries, other than Australia and the U.S., who are considering building a launch complex?

Answer 4: We do not know of any countries in the Pacific Rim who are considering building a launch complex.

Question 5: How does a launch site's proximity to the Equator affect the payload capacity for a launch into equatorial orbit? How would the payload capacity for a given ELV differ as between a launch site at Cape Canaveral, Florida, versus Wallops Island? Versus Hawaii?

For a communications satellite, doesn't this additional payload capacity convert to increased time on station and, thus, additional revenues for the satellite owner?

Answer 5: For launches into equatorial orbit, the payload weight capacity of a given launch vehicle decreases the further the launch site is located from the equator. Launch vehicles launched from sites not located on the equator must perform an orbital plane change to achieve an equatorial orbit. In executing the orbital plane change, the launch vehicle incurs a velocity penalty (measured in lost-feet/second) which it must expend additional fuel to overcome. The additional fuel needed to execute the orbital plane change translates into lower payload weight carrying capacity.

A communications satellite launched to geosynchronous orbit from Hawaii would incur a velocity penalty of approximately 500 ft/sec over a satellite launched to the same orbit from the equator; the velocity penalty for the same launch from Florida would be approximately 1100 ft/sec, and from Wallops Island would be approximately 1900 ft/sec.

Increased vehicle payload capacity due to launch from a site closer to the equator may result in increased time on orbit for the payload, since it allows additional stationkeeping fuel to be carried into orbit on the spacecraft. However, this may not of itself guarantee additional revenues for the satellite owner. Satellite launch contracts generally require that the commercial launch provider be able to deliver the spacecraft to orbit with sufficient stationkeeping fuel to last for the planned mission lifetime of the spacecraft. Additional fuel may allow the spacecraft to stay on orbit beyond its planned lifetime, assuming other spacecraft components remain operative. But the ability to stay on orbit longer does not guarantee continued function of the spacecraft for the longer period, and the owner may find it better to launch a new replacement spacecraft with increased capacity and a longer lifetime, than to continue to operate the old one. It cannot, therefore, be concluded that increased time on station automatically translates into additional revenues for the spacecraft owner.

Question 6: What future types of satellites do you envision that would use a polar or near polar orbit? Would these satellites be eligible for launch from a commercial space facility?

Answer 6: The primary polar satellite program under consideration at this time is the polar platform configuration associated with the proposed Earth Observing System (EOS). The EOS program includes two series of well-instrumented platforms designed to make simultaneous measurements of various aspects of the Earth's atmosphere, oceans, land and biota.

In order to meet the scientific requirements of the EOS program, each platform must be able to accommodate over 3000 kilograms worth of instruments leading to a total launch vehicle payload weight of over 15,000 kilograms. The only launch vehicle currently capable of lifting such a platform to a polar orbit is the Titan IV rocket, launched from California. The first launch of an EOS platform is expected in Fiscal Year 1998.

The ability to launch these platforms from a commercial launch facility would depend on the location of the facility (to achieve the proper orbit), the availability of a suitable launch vehicle (i.e. Titan IV or a rocket of similar payload capacity) and associated payload processing facilities, and compatibility between the available launch vehicle and program requirements. NASA's current policy is to turn to the private sector for the provision of launch services which meet these requirements. NASA has no siting specifications for such services, except to the extent that a particular location can provide the required orbital trajectory.

In addition to EOS, there are meteorological satellites, built by NASA for the National Oceanic and Atmospheric Administration (NOAA), which fly in a polar orbit. These satellites are part of an ongoing series of satellites, known as the NOAA-series.

The Global Geospace Science (GGS) Program - Polar Mission will be placed into an extended polar orbit using a Delta-II expendable launch vehicle. Because this program requires a 1993 launch, it seems unlikely that a commercial launch facility could be available to meet this schedule.

Finally, NASA is likely to require several polar orbit launches of small to moderate size spacecraft in the Explorer and Earth Probes series during the next decade. Depending on the capabilities of a commercial launch facility, some of those future (but not yet specified) polar orbiting missions might be able to utilize a commercial launch facility.

Question 7: If the U.S. chose to build additional launch pads at a new or existing site, how do the existing or proposed U.S. launch sites rank in terms of the greatest flexibility in reaching a variety of different orbits from equatorial to polar?

Answer 7: The types of orbits that can be reached from a given launch site, and the inclination of the orbit, are restricted not only by the site's geographical location, but also by the land masses downrange which will be overflown and potentially impacted by expended launch vehicle hardware. Overflight of populated areas must either be avoided, or they must be far enough downrange that overflight risk is minimal.

Existing U.S. facilities on the east coast (Cape Canaveral AFS/Kennedy Space Center or Wallops Flight Facility) are used for launches to geosynchronous or low inclination orbits, because of the earth's easterly rotation. Launch azimuth limits are 44 - 110 degrees for launches from Cape Canaveral. The azimuth limits for launches from Wallops are 90 - 109 degrees (northern corridor) and 126 - 129 degrees (southern corridor). Azimuths between 110 - 126 degrees from Wallops are restricted to avoid overflight of Bermuda.

Vandenberg Air Force Base is used for launches to polar and high inclination or retrograde orbits. Launch azimuth limits are 147 - 213 degrees for launches from Vandenberg.

The proposed Hawaii launch sites would have launch azimuth limits of 90 - 180 degrees, and would have virtually unlimited downrange impact areas for the launch of most launch vehicles.

Hawaii could, thus, support launches to both geosynchronous and polar orbits and would have somewhat more flexibility in this regard than any existing range; although Cape Canaveral can accommodate launches to lower inclinations (below 90 degrees) and Vandenberg can accommodate launches to higher inclinations (above 180 degrees).

Question 8: How significant is weather in assessing the desirability of a specific launch site? Has weather been a significant problem at Cape Canaveral in terms of causing delays in launches? How about the likelihood of lightning, is that a factor to consider?

Answer 8: Weather, particularly thunderstorm activity and high winds, are factors which may be considered in assessing establishment of a new launch site. The NASA Kennedy Space Center and Cape Canaveral Air Force Station, located on the east coast of central Florida, are situated in a region which experiences a high level of thunderstorm and associated lightning activity, particularly in the summer months. Due to the high level of lightning experienced at the Florida launch site, NASA and the USAF have established a state-of-the-art weather forecasting and lightning detection/protection system. This system has reduced the impact of weather to both day-to-day launch operations as well as launch day activities.

Although there have been instances where thunderstorms and lightning caused launch delays; high upper atmospheric winds have been the overall prime cause for weather driven launch delays at both our east and west coast launch sites. In the aftermath of the Challenger accident and an Atlas-Centaur failure caused by induced lightning, a revised set of weather launch constraints applicable to both the Space Shuttle and unmanned launch vehicles has been developed for use at any launch site to mitigate the affects of weather, especially lightning on launch activity.

Question 9: What is the current status of insurance liability for commercial launchings? Please cover third party liability and property damage (especially coverage for Government property at national ranges). What coverage is provided or assumed by the U.S. Government? What policy or regulatory changes are anticipated?

Answer 9: NASA defers to the Department of Transportation for insurance requirements for ELV launches required to be licensed under the Commercial Space Launch Act. For NASA programs launches, the agency generally utilizes its authority under Public Law 85-804 to indemnify private sector launch contractors, saving the cost of insurance.

Responses to written questions submitted by Chrm. Gore resulting from the May 15, 1990, hearing.

Commercial Space Policy

Question 1: Mr. Rose, as you know, there has been a great deal of discussion about the importance of having a stable and consistent commercial space policy for the future.

a: What is NASA's commercial space policy?

b: Are you satisfied with the overall approach of this Administration in developing a commercial space industry? What can be done to provide more stability and consistency toward space commercialization?

c: One of the witnesses on our second panel will argue that the U.S. government does not need a single commercial space policy -- but rather a flexible set of guidelines appropriate to the particular technical and market conditions for each area of activity. Would you agree with this approach? If so, what are the drawbacks in not having a broader, more comprehensive commercial space policy?

Answer 1a: Pursuant to the stated objectives of the 1982 National Space Policy, NASA has established a Commercial Space Policy which sets forth the goals, principles, and initiatives outlining the agency's efforts to foster a conducive environment for private investment and involvement in space. A copy of NASA's Commercial Space Policy established in October 1984 is enclosed to this statement.

b: NASA is most satisfied with the attention being given to the commercial development of space by the Administration through the activities of the National Space Council (NSC) and its staff. We are particularly pleased by the efforts of the NSC to ensure consistency of policy and avoid perturbations to the management of commercial space initiatives. Further stability in the policy environment for the commercial development of space would be assured through closer coordination among the government agencies involved and by long-term funding commitments for space commerce from Congress.

c: A single commercial space policy, and evidence of the Administration's commitment to supporting its implementation, are important to creating a favorable environment for private sector investment in space. However, maintaining a single-policy approach may, from time to time, require action in support of one sector of the commercial space industry to the short-term disadvantage of another.

National Space Council Review

Question 2: Earlier this year, the National Space Council initiated a review of the commercial space policy in this country, focusing on the status of the commercial space market and implementation of the commercial space provisions of the National Space Policy. It is my understanding that the Space Council review will lead to the development of a new commercial space strategy.

a: What role has NASA had in this review thus far?

b: What changes do you anticipate from this review? Will it result in a new Bush Administration policy for commercial space programs?

Answer 2a: NASA has been a full participant in the NSC Working Group that is conducting the review.

b: It is premature to speculate on the specific outcomes of the review. While some new policy directions may result, the principal focus is to define a federal strategy for implementing the commercial space policy goals contained in the President's National Space Policy.

Federal Support

Question 3: In the previous Administration, commercializing an industry typically meant the elimination of any Federal assistance. By and large, this was the original design for Landsat and satellite remote sensing.

a: In your view, is Federal support of the commercial space industry -- whether it be direct or indirect -- needed to ensure its continued development?

b: To what extent do foreign governments subsidize or provide assistance to space-related industries in their respective nations?

c: In your view, what is space commercialization? Is there a difference between commercialization and privatization?

Answer 3a: Continued federal assistance is needed to support the commercial space industry. Because the market for commercial space products and services is still in the early stages of development, high costs and technical and market risks characterize this industry, just as they did the railroad, air transport, and telecommunications industries before maturation.

b: All nations with space-related industries (including the U.S.) provide government supports of some kind to these industries. The extent, method, type, and quantity of support provided varies with each country and with each industry within each country, and can be very difficult to ascertain or even to identify. For example, recent trade deliberations led by the U.S. Trade Representative concerning the Chinese launch industry recognized that accurately quantifying true production costs in non-market economies, such as those in China and the U.S.S.R., is probably not possible. Neither is identifying those costs as either government supports or industry costs. Even trying to identify true costs and the amount of government supports for

Arianespace, the European launch firm, is problematic because of the number of nations involved, the fact that government agencies are actually shareholders of Arianespace stock, the use of subcontractors in each nation, the use of national banks for financing, and other practices.

In addition, other industries, like material processing in space, telecommunications, and remote sensing, also involve much government sponsored and supported research. Some of the supports involve simple use of government laboratories, others include substantial government funding, and others lie in between.

c: On the basis of recommendations made by the Commercial Programs Advisory Committee, regarding the negative connotations associated with this term, NASA avoids using "commercialization" to describe the commercial development of space. "Commercial development of space" involves the use of space technology to bring new products and services to the marketplace to meet current and future market needs. The markets for these goods and services will ultimately be located in the private sector, with decreasing dependence on the government as a customer. The commercial development of space takes place in the private sector and involves private sector investment and research and development (R&D), with the aid of a supportive government policy environment.

Privatization is the process of transferring a function from the government to the private sector, and may typically include the transfer of systems, hardware, and procedures needed to carry out this function.

Centers for Commercial Development of Space (CCDS)

Question 4: Mr. Rose, much of your testimony focused on the 16 Centers for the Commercial Development of Space. These CCDS's are involved in a variety of work on differing technologies and commercial space applications.

a: What are the types of products that are being developed at the CCDS's?

b: Over the years, as work levels at the CCDS's have increased, the level of Federal funding for their activities has risen. Has the level of contribution from the private sector increased as well? What percentage of funding for the CCDS's is public versus private?

Answer 4a: The CCDS's are currently developing a commercial space data base in the following scientific and technical disciplines:

a. Materials Processing (metals, ceramics, crystals, alloys, polymers, thin films, and glasses)

b. Remote Sensing (value added to space-derived data)

c. Life Sciences (protein crystallography, animal and plant cells, tissues, anomalies-diseases)

d. Robotics (machine vision, sensing systems, manufacturing technologies)

e. Space Power (energy generation and converting systems, energy storage, distribution and thermal managements systems)

f. Propulsion (chemical and electrical, microgravity fluid management, and propulsion system laser materials processing)

g. Structures (polymeric, metallic, inorganic, and organic composites, films and foams, and tribology)

This data base will be used to develop processing techniques in space and eventually improve materials and/or products that may be developed in space or on Earth. Such materials will be first seen in advanced pharmaceutical and biotechnologies, super conductors, advanced electronics and microcomputers, improved glasses, ceramics, and more efficient energy systems.

To date, 18 patents have been approved with 41 additional patents in the application process. There have been 778 scientific and technical papers published in refereed journals with an additional 91 publications in work, and 5 spin-off companies with new products created or in process.

b: Yes, the annual industry in-kind and cash contributions have increased from $1.0 million to $35 million since the program began in 1985.

The estimated funding of public money versus private money for 1990 is estimated to be 35 percent versus 65 percent This includes, industry in-kind as well as cash value, i.e., people, facilities, hardware, software, and technologies.

CCDS Launch Procurement

Question 5: Mr. Rose, in your statement, you referred to a significant number of CCDS payloads awaiting transportation to space. In that regard, your budget for FY 1991 includes a new initiative of $33 million to transport these payloads to space.

a: How are transportation services procured for these CCDS payloads? Should the individual Centers be responsible for buying their own launch vehicles, or should it be left to the Office of Space Flight?

b: Why are commercial launches needed for the CCDS payloads?

Answer 5a: Transportation services are procured through NASA in the case of Shuttle activities, including the Commercial Middeck Augmentation Module. In the case of the sounding rockets or expendable launch vehicles, services are procured by the CCDS's with government funds.

Launch vehicle services are found to be more expeditious and cost effective when procured through CCDS's. It is appropriate that NASA be the responsible organization for assuming responsibility for providing commercial support through the Shuttle activities; however, through the U.S. commercial launch service industry, this country has a budding opportunity to capture a portion of the world transportation market. We feel it is important to support this industry and the commercial use of space through the CCDS's. In this regard, we have developed programs at two CCDS's to provide commercial launch services for all of the CCDS's. The University of Alabama at Huntsville, Consortium for Materials Development in Space, procures the sounding rocket launch services and the University of Tennessee, Center for Advanced Space Propulsion will procure the Commercial Experiment Transporter launch support.

b: CCDS's and their industry members need frequent and quick access to space to expedite the development of their new technologies. They need a minimum of red tape and budget fluctuations to protect their commitments and new product potential. Commercial launch services offer this stability. Also, by procuring launch services commercially, an environment that encourages industry to develop new and less expensive ways to access space is created. Commercial launches support the demand of potential new markets that will require a dynamic and flexible, yet cost effective space transportation system. Fostering the development of commercial launch services firms offers an excellent opportunity for the U.S. to achieve a dominant world position in providing space transportation infrastructure.

Technology Transfer

Question 6: As you noted in your testimony, a second program under the Office of Commercial Programs is designed to encourage the transfer of NASA-generated technology to the private sector. In an effort to promote these "spin-offs," an annual publication is prepared highlighting the application of varying technologies developed in space to various aspects of the U.S. economy.

a: It would seem that this is an area that has not always gotten the attention it deserves by NASA. What additional efforts are being considered to better ensure that these NASA-generated technologies are applied to the private sector?

b: It was recently reported that the President of the Boeing Commercial Space Development Co. said that, while NASA's methods have improved, the Federal government must consider more radical plans to improve the flow of technology developed by NASA to the marketplace. What is being done by NASA to accomplish this?

c: What are some examples of technology spin-offs that occurred in 1989?

Answer 6a: Two major initiatives are being undertaken by NASA during the current year which will greatly enhance the transfer of NASA-developed technology to the private sector:

1) NASA was designated by Congress as the lead federal agency to establish a National Technology Transfer Center (NTTC) which will serve as a focal point for industrial inquirers seeking access to federally-developed technology and provide appropriate referrals to established technology transfer resources available throughout the Nation. Such transfer resources would include: the NASA Industrial Applications Center network and their technical and business assistance affiliates which are now located in 43 of the 50 States, NASA's Computer Software Management and Information Center, and, technical experts in all federal R&D laboratories, including those of NASA. NTTC, to be located in West Virginia, will commence operations in the fall at the conclusion of 8 months of intensive planning in which NASA and other federal agencies have participated. Once NTTC has gained effective operational capability in 1992, it is expected that U.S. industry will have more direct and efficient access to many sources of federal technology and technology transfer delivery systems throughout the Nation than is presently available.

2) The recent national policy emphasis on strengthening U.S. competitiveness in the international marketplace has given increased significance to the secondary applications of NASA technology. In addition, recent congressionally-directed technology transfer policies (e.g., the Federal Technology Transfer Act of 1986) challenge NASA and all federal agencies to develop new ways of working with American industry to promote the use of technological advancements necessary to maintain U.S. competitiveness. In November 1990, in support of this national technology transfer agenda, NASA will sponsor its first agencywide conference in technology transfer to promote a greater awareness of NASA's technical resources and their commercial use potential within the nonaerospace industry.

Planned as an annual conference, TECHNOLOGY 2000, will be held at the Washington Hilton on November 27-28, 1990. The goal of the conference is to: (1) increase awareness of existing NASA-developed technologies that are available for immediate use; and, (2) lay the groundwork for effective use of emerging technologies being planned and developed for future missions. It is expected that 1,500-2,000 corporate executives, including chief scientists and engineers and other research directors from the nonaerospace industrial sector, will attend TECHNOLOGY 2000.

b: Many of NASA's contractors possess innovative technologies developed for NASA that could be transferred more directly to nonaerospace firms for secondary commercial applications. During the FY 1991 timeframe, NASA will make a concerted effort and devise effective means to involve major R&D contractors in the technology transfer process. NASA's efforts will be designed to bring opportunities for direct interaction to the attention of its contractors so that concentrated initiatives in technology transfer can take place between aerospace and nonaerospace private entities to foster broader participation and use of contractor-developed scientific and engineering advances.

Additionally, NASA will increase its efforts to create broader awareness of NASA technology availability. The TECHNOLOGY 2000 conference initiative, described above, exemplifies such increased emphasis. Greater awareness, of course, will engender a higher degree of interaction with nonaerospace industry than has previously been the case. Such efforts are expected to lead, for example, to a significant increase in cooperative R&D agreements between NASA and the private sector for the transfer and commercial use of aerospace technologies by U.S. industry.

c: Technology spin-offs of aerospace technology occur in a wide range of industrial and commercial uses, as well as areas of public need and human concern. The specific examples described in the enclosed articles are representative of the spin-offs which culminated in 1989, some following many years of application and adaptation by participating organizations.

Responses to written questions submitted by Sen. Pressler resulting from the May 15, 1990, hearing.

Question 1: What is the appropriate role of government in stimulating the private sector involvement in civil space activities?

Answer 1: There are a number of roles the government can play in stimulating private sector space enterprise. NASA and the Departments of Defense, Transportation, and Commerce contribute in various ways to foster, encourage, and stimulate expanded involvement and investment in commercial space activities, and bring about the commercial application of space technology.

A common role that these agencies play is as a customer of U.S. space industries to meet their institutional needs. Increasingly, private companies are becoming the providers of space services that a few years ago were available only through the U.S. Government. New entrepreneurial firms have entered the space industry to provide launch vehicles, space facilities, payload processing services, satellite services, and various other infrastructure services for the military, civil and commercial sectors, often more efficiently and at more reasonable prices. These products and services may be available at lower costs because industry is able to develop them in a truly commercial way, working as other industries do, in a for-profit mode, using market-driven methods. Government specifications are not so much the driving force as is design and technology. Some of these private firms are on the verge of becoming viable business operators but are being challenged by strong international competitive forces. Therefore, purchasing products and services from the private sector may not only be economical for our government,-but also contributes to the strong economic future of U.S. industry in space and U.S. competitiveness abroad. This may also contribute to the U.S. high-tech balance of trade.

Under the Commercial Space Transportation Act, amended in 1988, the U.S. Government can undertake research and development (R&D) aimed at reducing the cost of space transportation and related services, enter cooperative agreements with industry to encourage private sector R&D, and provide for timely transfer of government-developed space technology to the private sector in a manner which protects the commercial value of the technology. NASA and other government agencies develop technology and provide technical assistance to the U.S. space industry, each to a greater or lesser degree. Research within the government sector draws upon the existing technological expertise of government agencies. Also, having the government provide valuable technology frees up resources in the private sector for the commercial development of products and services. These valuable resources can also increase the benefits of R&D already being done by the private sector.

The Departments of Commerce, Transportation and Defense also play an important role in regulating U.S. space industries. This role is necessary to ensure compliance with export control statutes and safe operations of launch vehicles. More tangible resources, such as launch facilities and grant funding, are provided by NASA and the Department of Defense to the U.S. space industry. In addition, the National Space Council is currently conducting an interagency review of commercial space policy with an emphasis on ensuring that appropriate provisions of the National Space Policy are being effectively implemented.

The Centers for the Commercial Development of Space (CCDS) are an important component of NASA's mission--to operate programs that help industries develop commercially marketable products and services and cost-effective commercial space transportation systems and infrastructure. The mission of NASA's Office of Commercial Programs is to facilitate the private sector's commercial development of space as a new sector of the national economy. NASA's resources multiply when leveraged by CCDS's, thereby strengthening its investment. The average ratio of industry matching funds (measured in cash and in-kind services) to government funding for the 16 CCDS's is 2.2 to 1. The ratio of just the first five CCDS's, established by NASA in 1985, has risen to 3.4 to 1.

Question 2: Is much of the market for commercial space products and services driven by government needs as opposed to private sector demand? Is there really a private sector market for commercial space activities, and, if so, what are those markets? Which markets have the greatest potential for growth?

Answer 2: The current market for commercial space products and services is driven primarily by government needs. However, U.S. space industry, on its own and in conjunction with NASA programs, has developed products and services that meet current civil space requirements and have the potential to meet future private sector demand as well. New commercial opportunities are emerging in several sectors of the market, particularly for launch services and space facilities, but also in satellites, scientific research equipment, materials processing, and life sciences.

Companies that provide launch services to the U.S. Government also provide launch services to transport commercial satellites and other structures into space. Supporting infrastructure and facilities open up opportunities for using space as a research laboratory, to manipulate materials and scientific processes to achieve results far superior to those obtained from similar experiments on Earth. Life sciences and microgravity research apparatus, materials processing hardware, data support, automated sample-return systems, and payload preparation equipment, for example, are supporting infrastructure that have provided the necessary means for conducting these research experiments in space.

Materials processing in space could lead to potential advances in medicine, semiconductors, substrate materials for electronics, thin-film technology, polymers, glasses, plastics, high-performance alloys, agriculture and food technology, and energy systems, allowing this sector of the market one of the greatest potentials for growth.

Some satellite applications that appear the most promising for future commercial markets include meteorology, resource development, navigation, geopositioning, and asset tracking.

High-yield products and services will be the key to successful market cultivation for the commercial space sector. Technological innovations will allow businesses to develop such products and services. As technology results in product development, markets will emerge and demand will grow. This "technology push" will be an important factor in the success of the commercial space sector.

Question 3: What are some of the success stories for the commercial programs under your jurisdiction?

Answer 3: Since their inception in 1985, NASA's CCDS's have played a vital role in developing new commercial space industries through their involvement in the research and testing of potentially commercially viable technologies. Sixty-one new technologies are currently defined by the CCDS's. Eighteen of these technologies have been patented, while 41 more are awaiting confirmation.

High-quality protein crystals were grown in space by researchers from the Center for Macromolecular Crystallography at the University of Alabama, Birmingham. These tiny crystals are valuable tools for scientists who are working to develop powerful new drugs to combat cancer, high blood pressure, organ transplant rejection, rheumatoid arthritis, AIDS, and many other diseases. The crystals were generated from experiments performed aboard Space Shuttle flights STS-26, STS-29, and STS-32.

Other benefits from CCDS scientific experiments in space could be derived from polymer membranes, which are used in the separations industry for such applications as desalination of water, filtration during the processing of food products, atmospheric purification, purification of medicines, and dialysis of kidneys and blood. The Center for Advanced Materials, Columbus, Ohio, through experiments performed aboard the Space Shuttle, has been able to produce well-ordered porous thin-film membranes with significant structural differences from similar materials produced on Earth. Future microgravity experiments involving crystals and polymer membranes will hopefully make valuable contributions to the fields of biomedicine, chemistry and meteorology.

A stronger, more efficient power supply applicable to laser work is currently being marketed by an affiliate of the Center for Commercial Development of Space Power at Auburn University. Maxwell Laboratories has been successful with this first CCDS technology spin-off occurring during 1989, and continues to work with the CCDS on technological innovations in space power.

Last year also witnessed the first corporate spin-off resulting from involvement with a CCDS--BioCryst, a Birmingham, Alabama, pharmaceutical company, was formed to apply the tools of X-ray crystallography and computerized molecular modelling to the development of new pharmaceutical compounds. BioCryst has applied for patents for its work on anticancer drugs.

Stimulating cost-effective commercial transportation and infrastructure ventures is another way in which the CCDS's have helped to move technologies from the laboratory to the marketplace. The need for space transportation and supporting infrastructure is evident given the fact that each technology will require a specific number of flight tests to mature it to the point that a decision can be made regarding the viability of commercial application.

In March 1989, the Consortium for Materials Development in Space, at the University of Alabama in Huntsville, successfully launched six CCDS-developed payloads on a commercially provided launcher, Starfire, for the vehicle's first suborbital flight, named Consort 1. The entire effort to integrate the payloads and commercially procure the launch services, and launch and recover the payloads took only 9 months, compared to the traditional 18-24 months. Though, Consort 2, the second launch attempt of the sounding rocket in November 1989, malfunctioned, the Starfire's most recent flight, Consort 3, on May 16, 1990, accomplished its mission by successfully carrying its payloads to conduct those experiments which could not be completed on Consort 2.

The CCDS's are also planning and initiating a variety of hardware development projects. One such project is the Wake Shield Facility, in its second year of development at the Space Vacuum Epitaxy Center at the University of Houston. The Wake Shield will provide a high ultrapure vacuum by pushing aside stray atoms and molecules encountered by the Space Shuttle in low Earth orbit so that multilayered thin films, that can be used in opto-electronics, microwave amplifiers, and various electronic applications, can be grown.

Question 4: The FY 1991 budget request for your Office represents a 79% increase over the FY 1990 funding level. What would the additional funding go towards? How would NASA accommodate any cuts in the budget request for your office?

Answer 4: The fiscal year 1991 budget request of $101 million for the Office of Commercial Programs is an increase of $44.5 million over the FY 1990 budget of $56.5 million. Almost all of the increase is to assure access to space for the technology payloads developed by the CCDS's. This includes increases of approximately $6.1 million for flight payload developments for the CCDS's, about $4 million for flight preparation and integration, and approximately $31 million for additional commercial transportation. Commercial transportation will include a commercially provided payload module, sounding rockets, and expendable launch vehicles.

The impact of funding reductions would have to be carefully assessed because of the highly integrated nature of our programs.

It is clear, however, that a funding reduction would reduce flight opportunities for important technology payloads.

Question 5: The Centers for the Commercial Development of Space appear to be an excellent way of accelerating the commercial exploitation of aerospace technologies. How are the decisions made on which technologies will be studied and where a Center will be located?

Answer 5: CCDS's are competitively selected consortia. In 1985, 1986, and 1987, NASA conducted three separate competitions to select the Centers. Each CCDS proposal was expected to concentrate on one identified technology development area. In the first solicitation area, there were no specific guidelines as to a preferred technical area; however, a number of general R&D areas were listed that could potentially benefit from the unique attributes of the space environment and space programs. These target areas were developed by NASA and the scientific and business communities. In the second and third solicitations, the previous RFP winners were identified along with the technical area they had chosen, and potential applicants were encouraged to submit proposals and institutional arrangements that were novel and that might depart from earlier successful candidates. There were no geographical considerations given to the selection of any of the 16 CCDS's.

Since most CCDS resources come from members whose ultimate goal is the development of economic return from space and eventual independence from their NASA base grant funding, they are left to their own business, scientific and entrepreneurial acumen to select the focused technology area. After a CCDS is selected, decisions on resource allocations for technology development are made by the consortium members with the CCDS director and staff.

Responses to written questions submitted by Sen. Lott resulting from the May 15, 1990, hearing.

Question 1: The "Small Business Innovative Research" (SBIR) pilot program currently underway at Stennis Space Center is designed to take an active and aggressive approach to stimulating commercial growth of small businesses' involvement in federally developed technology programs. Can you provide an overview of the project progress to date and give your views and observations concerning this initiative?

Answer 1: The SBIR program at Stennis Space Center (SSC) is not a "pilot" program. SBIR is a congressionally mandated activity and the SSC program is conducted within the framework of the legislation that established the SBIR program. SSC has incorporated the SBIR program as an element of their overall program to assist small business development. The SSC has initiated an aggressive program of outreach and assistance in high-technology small business development in the five-state area surrounding SSC (Mississippi, Louisiana, Tennessee, Arkansas, and Alabama). One important objective of this activity is to assist small business to develop commercial applications of space technology developed in NASA programs.

The SSC program addresses not only small businesses, but state and local business development agencies as well. An important step has been the formation of a 3-year pilot program called the "Space Technology Small Business Initiative" (STSBI) which is being managed for SSC by DARKAT, Incorporated, a local small business firm with capabilities in program development and management. Activities thus far have emphasized outreach to business development organizations and small businesses in the target area. In addition to outreach, future activities will emphasize the transfer of federally funded technology to small businesses, assistance in identifying commercial applications of selected space technologies, and assistance in developing those applications.

SSC outreach has included the development of agreements with state economic and community development agencies on technology transfer and business development support; on-site workshops at SSC for business development groups and small businesses; off-site presentations to local and regional development groups; and, development of a "Gateway to NASA" facility in Mississippi to help individuals, small businesses, and civic groups learn more about technology transfer opportunities, mechanisms for assistance within NASA, and NASA contacts.

Four technology transfer/technology utilization workshops, one commercial planning workshop, and one SBIR workshop have been held at SSC, reaching almost 400 people. SSC and DARKAT personnel have also participated in approximately a dozen off-site meetings and conferences reaching more than a thousand other individuals. Media coverage of small business outreach activities has included TV, radio, and newspaper reports in the region around SSC. Contacts have been made and several support agreements have been reached with business and community development agencies in each state in the target area. In addition, at least 1,200 individuals and organizations have obtained information on NASA, technology transfer, and technology program opportunities through the Gateway facility.

STSBI activities, which are an important focus of the total effort, concentrate on using the SBIR Program to foster small high-technology business development in the target area. Two specific objectives include improving the commercial success of SBIR projects by small businesses in the target area and, on a broader scale, developing a "process model" for small business development and commercial activities which could be applied to any geographical region and circumstances. Funds for STSBI are provided by the NASA Office of Commercial Programs, whose programmatic responsibility is to foster commercial uses of space.

We are pleased with progress to date. SSC and DARKAT have launched an energetic outreach program. Much has been accomplished in the first year: the contacts that have been made with small businesses, the awareness of NASA technology transfer and program opportunities that has been developed, and the support network that has been formed are all major enabling accomplishments. We look for important results, starting this year with a larger number of high-quality, innovative, award-worthy SBIR proposals from the target area than in the past. It is also expected that a number of projects having attractive commercial applications will be identified this year and that activities to exploit them will commence. And it is hoped that, within the next year, significant small business support will materialize based on state and local development commitments.

Question 2: As you well know, a great deal of emphasis is being placed on potential commercial applications of the awards presented in this pilot program. I have already seen an immense increase in the awareness of the SBIR program among those in the business community because of the Stennis Initiative, and I believe we will see this translated into an increase in proposals. Have any measures been taken on NASA's part to ensure that adequate numbers of SBIR projects are placed at Stennis to support this initiative and to provide solid data for evaluating the success of the initiative itself?

Answer 2: Although the success of the SSC "Space Technology Small Business Initiative" (STSBI) will not depend on the number of SBIR projects managed by SSC, it is desirable for SSC to manage a reasonable number of SBIR projects while pursuing the STSBI objectives. To encourage and support their activities in the coming year, we anticipate that it may again be appropriate to augment the nominal 1990 Phase I award allocation for SSC.

Nominal Phase I award allocations each year for all NASA field installations are proportional to the numbers of proposals the field installations receive and to their fractions of the total NASA research and development (R&D) budget. Adjustments are made to account for special circumstances. For the case in point, we more than doubled the SSC award allocation in 1989 in order to encourage SSC planning for small, high technology business development and commercial applications of space technology, which was subsequently embodied in the STSBI Program. For 1990, final award allocations remain to be determined since they will be based on actual distributions of proposals and overall R&D budget fractions for all nine NASA field installations, and on any other special circumstances which should be accounted for.

To further support STSBI objectives, we requested SSC to examine the commercial application potential of all current SBIR projects managed by all nine NASA field installations in areas of technology that would relate to SSC research and commercial application objectives. That examination should identify many projects which could be suitable for further consideration in the STSBI initiative. By this means, SSC can obtain a much larger group of candidate projects than could be found in the relatively small number which they alone manage. We expect SSC to pursue this activity later this year.

Question 3: I truly believe that the SBIR program could be one of our best technology transfer tools, but it appears that many of the agencies that use SBIR's put most of their emphasis on research and development -- for which they already have funds budgeted. What do you see as possible solutions to improving the SBIR program results regarding the commercial aspect in the original legislation?

Answer 3: It should be noted at the outset that SBIR projects are not separate activities in the agency's annual R&D program budget. Instead, SBIR projects are integral parts of the total agency R&D program. Though funded through a special set-aside from the entire R&D budget, they are still directed to the pursuit of the same objectives for which the R&D budget was appropriated.

It should also be noted that SBIR is, in fact, a successful means of technology transfer to the private sector, differing from other means in one important respect: it is designed to benefit first the firms that have developed the technology for the government. The SBIR legislation gives SBIR contractors initial exclusive rights to further develop and exploit the commercial potential of the results of their research. The law further protects the small business' position for a period of two years following completion of the research by preventing the government from publishing the results without their consent.

The commercial aspect of the original SBIR legislation is noted in one of the four stated SBIR program purposes, namely, to increase private sector commercial applications of innovations derived from federal R&D. Another stated objective of the legislation, however, is to use small businesses to meet federal R&D needs. The Small Business Administration (SBA) described the hierarchy of these objectives in its SBIR Policy Directive by asserting that "The first two phases [of the program] will help agencies meet their research or R&D objectives" and "The third phase, where appropriate, is to pursue commercial applications from the Government-funded research or R&D to stimulate technological innovation and the national return of investment from research or R&D or for further contracting or grant activities with federal agencies through non-SBIR funding agreements."

Accordingly, our first obligation is to select SBIR projects that assist the agency in achieving its technical mission goals, whether or not the small business performing the research is able to develop commercial applications of the results. Nevertheless, we want all small business offerors to do everything possible to identify and pursue potential commercial applications of the innovations they propose, and we provide special encouragement and incentives for their doing so. In particular, when we have the choice of selecting projects which only assist us in our program goals, or of selecting projects of similar technical merit which not only assist us in our mission but also provide the small business an opportunity to pursue commercial applications of the project results, we choose the latter.

Considering the nature of NASA R&D requirements, it is not possible to guarantee that all technology developed in the NASA SBIR program will have either immediate or future commercial applications after it has been developed to meet the NASA requirement, or even that it will have significant NASA applications. Nevertheless, the history of NASA's technology utilization program shows remarkable success in the transfer of space technology into commercial applications or "spinoff."

In assessing our SBIR Program, we are gratified to find that many projects (at least one in four) have already proceeded into commercial applications and that the majority of the SBIR contractors are working diligently in their own interests to develop commercial applications. Because commercial applications may require many years of both product development and market development or acceptance, the commercial successes in our program may be attributed in great part to the entrepreneurial energies and persistence of the small businesses. The ability of NASA personnel (or of the government generally) to assist in that process is limited since most lack the experience or expertise of the private sector in that field. Further, we may not use SBIR funds to support those endeavors.

Question 4: How much weight does NASA currently give to the commercial potential when you evaluate SBIR proposals?

Answer 4: The commercial potential of SBIR is given consideration in both Phase I and Phase II selection processes. The criteria the field installations use in evaluating Phase I proposals include (1) the scientific and technical merit, (2) the qualifications of the offeror to conduct the proposed research, (3) the anticipated benefits (technical and economic) of the results, and (4) the merit of the proposed work plan. For criterion (3), 60 percent of the score is allocated to the anticipated benefits of the proposed research to NASA in the conduct of its mission, and 40 percent to the anticipated commercial application potential of the results of the research.

For Phase II, each proposal's commercial potential is scored and, as required by the SBA's SBIR Policy Directive, special consideration is given to those proposals having approximately equal technical merit which have obtained a commitment from the private sector for funds to support commercial application development in Phase III. About half the firms submitting Phase II proposals obtain such commitments, and those commitments have been used each year as determining factors for the final selection of a number of winning proposals.

Question 5: What technical assistance is provided to the selection staff in determining the commercial merit and potential of an SBIR proposal?

Answer 5: Submitters of both Phase I and Phase II proposals are required to address the commercial potential of their proposed innovations, and their intentions to pursue them. The civil servant personnel at the NASA field installations who perform SBIR proposal evaluations and make selection recommendations base their judgments of commercial potential largely on information provided by the offerors' representations of commercial prospects and plans. NASA field installation evaluations and assessments are reviewed for apparent validity and significance by selection personnel in Headquarters. Funds are not generally available at the NASA field installations or in Headquarters for obtaining outside help in this process.

Question 6: Forty-four percent of the total NASA Phase I SBIR awards [in 1989] were made to small business firms in only two of the fifty states. In addition, multiple and repetitive awards are often made to single firms without entering Phase III or commercial application. What can be done with the present program to improve the geographic spread of the awards, and the distribution of the awards to more small business firms?

Answer 6: As required by law, the SBIR Program is a competitive procurement. The SBA SBIR Policy Directive states that "Proposals shall be evaluated on a competitive basis and awards shall be made primarily on the basis of scientific and technical merit. Secondary considerations may include program balance, critical agency requirements, and whether the proposal indicates potential commercial applications in addition to meeting Agency needs." Both the enabling legislation and the SBA Policy Directive are silent regarding regional distribution of awards or the numbers of awards that may be placed with any small firm.

Our first requirement in selecting SBIR awards has always been technical quality and value to NASA. NASA does not compromise the selection procedure by selecting SBIR proposals for award on the basis of regional distributions, nor does any other agency to our knowledge do so. The national distribution of small, high-technology firms is clearly quite nonuniform, with significant concentrations in several geographical areas noted for their high-technology business communities. That fact is reflected in the distribution, by state, of the proposals we receive each year. And as a consequence of the competitive nature of the program and our intention to select the highest quality and most valuable proposals for award, the distribution of awards tends to reflect the distribution of proposals.

Without further guidance or direction from the Congress and the SBA, SBIR award distributions will probably continue to reflect the foregoing facts in all SBIR programs. Nevertheless, NASA has thus far made awards in 41 states, the District of Columbia, and Puerto Rico. Our analysis shows, however, that proposal success ratio (the ratio of the number of awards made to the number of proposals submitted) is not necessarily higher in states having large numbers of awards than it is in most states having lower numbers of awards (given that the numbers of awards and proposals under consideration are large enough to have statistical significance).

We have also found that the number of awards made to individual firms tends to reflect the fact that firms writing numerous high-quality proposals for high-potential innovations frequently fare best in the competitive process. For an agency to fail to reward their innovativeness and competence to perform R&D needed by the agency and, in many instances, to fail to recognize their motivation and ability to develop commercial applications of their results, would be contrary to the intent of the legislation as we understand it. Still, the success ratios of aggressive, high-quality firms seldom differs much from the averages for all competing firms (approximately one in nine). It is noteworthy that about half the firms with whom awards are placed each year are new to the program. In 1989, Phase I awards were placed with 200 firms, 103 of whom had received no prior NASA awards, including 77 who had submitted proposals for the first time.

In our view, arbitrary increases of the number of SBIR awards by an agency in states presently receiving relatively few awards would be contrary to current guidance of the Congress and SBA. We believe that outreach and other supportive activities by the federal agencies having SBIR programs is quite valuable in stimulating greater interest and involvement of small businesses in such states. For this reason, NASA supports an active outreach program to inform and encourage small businesses not presently involved with SBIR, or who may have been unsuccessful in their initial efforts to win SBIR contracts. In addition to the SSC STSBI program, the NASA outreach program includes participation in numerous SBIR informational seminars, NASA-sponsored small business opportunity conferences (which also emphasize minority opportunities), and cooperation with other federal agencies in joint outreach.

Continued federal agency outreach and a sincere desire to help is not enough, however. It is our view that increasing SBIR participation in states which presently have minimal small business participation in technological development and commercial applications of technology will ultimately depend on the interest in, involvement of, and continuity provided by state and local small business development organizations and agencies, coupled with the support of appropriate local financial institutions involved with economic development and growth. These agencies and institutions are essential; only they are able to provide the tangible business development support needed to nurture healthy, high-technology small business communities.

Senator GORE. Very good. Mr. Pawlick.

Mr. PAWLICK. Thank you, Senator.

I am going to discuss, as Jim said, first of all, our Center—I think we are doing some interesting and very informative space propulsion work—and then discuss a little about the ELV program.

CASP, the Center for Advanced Space Propulsion, is a part of the Center for Aerospace Research, CAR. That is a not- for-profit organization formed by the University of Tennessee and CalSpan in 1985 with the expressed purpose of getting the aerospace technology match between the university and industry. They made a proposal to NASA to develop this Center for Advanced Space Propulsion and in 1988 we were funded to do just that.

Our mission is to really strengthen U.S. competitiveness in space technology, particularly in the area of space propulsion, develop new space-related commercial products, and, of course, advance the commercial use of space and do it through forming a network with commercial users, people out there who want to apply their product, particularly space propulsion, and need a way to fly it. They may need some additional research to be accomplished. And we feel we can fill that need and we have.

I talked about our industrial partners. We have a number of them, 9 major industrial partners, and they extend all the way from what we call the aerospace giants—Boeing and Rocketdyne—to as small as a 4-man organization, Electric Propulsion Lab in California—all of whom are performing work in advanced space propulsion—arc jets, ion engines, resistojets—each of which has found some market out there, something they believe the commercial industry needs.

Now we are in a position, we think, to help them make that dream come true.

I have listed in my testimony a number of our partners. I think you would find them interesting. They do go from the very small up to the very large. And we have broken our focus within the Center down into looking at advanced chemical systems, looking at electric propulsion—that is probably our major thrust—artificial intelligence and expert systems, the problems of transferring propellants in space, microgravity fluid management—moving cryogens in space—and then laser material processing.

I think you are familiar with some of the work that the Laserlab has done at the University, and we are using that expertise as a way to draw industry in and solve some of those problems that can be solved using the Center for Laser Applications.

The real key to how we are doing. We started, as I said, in 1988. We are now employing, in one form or another, 35 research assistants, professors and CalSpan personnel. We have 9 industrial partners, 15 active technical projects, with 19 more on the books that are in some form of development.

The point there is there is a need out there. People have come to us and said they need to play in the space business. They want to be an active participant. Again, I invite you to attend our new building ribbon-cutting ceremony, which will be in October. The State and the Appalachian Region Commission——

Senator GORE. What date in October?

Mr. Pawlick. It is October, sir. That is as close as I will come. I am not the construction manager.

Senator Gore. Well, let me know as soon as you get a firm date.

Mr. Pawlick. I will. But the 2 organizations have allowed us to move into or construct a building, a 10,000 square foot building, right on the research park at UTSI, and we expect to take occupancy there.

The other part of my presentation or my discussion is about a presentation that we made to Mr. Rose and to the Office of Commercial Programs, because we believe that there is a role for ELVs in the commercial programs as long as we can get those commercial packages back.

Now right now that is being done admirably by the shuttle, but we see this as an adjunct to that. And let me to ask you to imagine a system in which, like the old Air Force Discoverer program or NASA's earlier Biosat program, we are using a small ELV. You could launch roughly a 1,000 or 1,200-pound payload which would have in it a support module or, let us say, a satellite with some experiments but primarily the thermal transfer, the power distribution system, the batteries, all those other support systems you need, and atop of that a reentry system in which you would have the scientific or, in this case, the applications payloads that industry would like to fly.

Within that volume then would be just payloads. So we would launch it. We have spoken to the commercial launch people and they seem to be pretty interested in this. But it would be launched via an ELV, stay in orbit anywhere from 15 to 60 days, depending upon the needs of the experiment, and then be reentered and recovered.

We think right now that it is possible, with the state- of-the-art increases that we have seen, that we could reenter it and land it at White Sands. We have spoken to the White Sands people and they are mildly interested but have reservations about targeting White Sands for a ballistic reentry. But, nevertheless, we think that we can overcome those.

The other plus to this program is the state-of-the-art improvements in parasails and in parachute technology, which would allow us to really pinpoint our landing much closer than the earlier programs had been able to do.

So that is sort of a synopsis of the program. We would look to this as being the way in which up to 168 potential commercial payloads could be placed into space. I get that number from a study that Lewis Research Center had SAIC perform, saying that that is the market that is out there. Now they are in different weight classes and some of them will want to be reflown. So we think, as Jim said, that there is a large subset of commercial activity out there who would like the flexibility of being able to stay in orbit for as long as they desire and be able to reenter and land, have very late access to their payloads.

So through that technique we think that maybe we have a way to satisfy that subset that cannot economically fly on shuttle. When I say economy I do not mean to say it is cheap to do any of these programs, but in this case we think we can satisfy the specific needs of the commercial user.

I guess the other thing that would be of interest is our approach to how you would organize to do this, because there is no organization around who performs this service today. What we are suggesting is that it makes sense to lay out a program in which we would commercially procure, through the request for proposal process, launch services, the support module that we discussed, the reentry system, the on-orbit support of all of that, systems engineering, and then integrating those payloads so that they can be put together and slid into the recovery system.

There are 6 separate areas that we would see going out in statements of work, tailored, we think more toward performance goals, performance objectives, which as we view the industry seem to favor fledgling industries. You know, of the large manufacturers, we cannot see too many of them that are players in these parts, with the exception of GE and some of the reentry folks.

Senator GORE. They have gotten over the excitement and they are no longer willing to work for nothing.

Mr. PAWLICK. Or work for a little. That is not true. I think they all are. But my whole point was the way we see the program structured is we would start with a concept of bringing these people on to do the work.

The CCDSs are not either equipped, necessarily, nor should they get involved in performing these functions. Our objective is to commercialize space through the use of commercial companies, not NASA-related centers or anything like that. So what we are suggesting is that we would set up a program management team, which would be myself and a few people from these CCDSs, but the majority of the effort that we are talking about here is contracted to as many as 6 companies who would be called upon to perform this mission.

We see it occurring in 1992 at the earliest. We think technology is here now. We do not intend to design the system and go out for bids. We intend to go out for bids based on performance, and then see what happens. So that is our approach.

If it is successful, we think we will have set up an infrastructure, if you would imagine it, of systems engineering, the launch vehicle and the rest where if it is successful we could back out of this program. That is true commercialization—when you can set up the infrastructure, you set up the transportation and then turn it over to industry and they become the people who market the technology.

That completes my presentation, Senator Gore.

[The statement follows:]

UNIVERSITY OF TENNESSEE-CALSPAN
CAR
CENTER FOR AEROSPACE RESEARCH

CENTER FOR ADVANCED SPACE PROPULSION

May 15, 1990

Joseph F. Pawlick, Jr.
Program Manager

Good morning, I'm Joe Pawlick, Program Manager for the Center for Advanced Space Propulsion, CASP, A NASA Center for the Commercial Development of Space. This morning I'll describe two aspects of our CCDS activity: our center activity which supports space propulsion and our initiative to assist in development of a transportation and infrastructure initiative which will support the commercial use of space.

First, some comments about our center. In 1985 the University of Tennessee and Arvin/Calspan formed the not-for-profit company, The Center for Aerospace Research (CAR). It was decided by the Board of Directors that CAR would be located at the University of Tennessee Space Institute (UTSI) outside Tullahoma. From that location, CAR could readily tap the expertise of the educational staff and research assistants of the university, and the professional staff of Calspan, one of the three operating contractors at Arnold Engineering Development Center.

CAR proposed to NASA that the unique educational and technical skills and facilities of the area would lend itself to establishment of a Center For Advanced Space Propulsion, a branch of CAR which could assert our Country's continued leadership in propulsion and prepare for the challenges of future missions. CASP was envisioned as a center in which advanced techniques such as artificial intelligence, neural networks, and computational fluid dynamics could positively effect existing propulsion systems such as the Space Shuttle Main Engine or future systems like ion or arc jet engines and enhance the competitiveness of the nation's propulsion industry. NASA found the CAR proposal attractive and grant funding was received in mid FY 1988. CASP joined four other centers which were activated in that year.

You may be aware of some of the significant achievements of other centers in the life sciences, material sciences, and earth sciences; CASP's mission falls in what some might consider a service, or infrastructure role. The focus of CASP's research supports industry needs in five primary areas: Chemical propulsion, Intelligent Systems, Propulsion Materials and Processes, Electric Propulsion, and Microgravity Fluids Transfer. In each of these areas we have found industry to have specific needs for which

CASP has been able to bring the talents of UTSI, UTK, and Calspan to bear and perform analyses, write or modify computer codes which optimize chemical engines, perform cryogenic transfer experiments, develop approaches to flight experiments, and will, this summer perform diagnostic tests on electric propulsion systems run in a refurbished vacuum facility at UTSI.

Our research is driven by commercial need and our industrial partners include both small businesses and aerospace giants. Boeing Aerospace, Rocketdyne, and TRW have found it to their advantage to team with CASP as have the four employee Electric Propulsion Lab, slightly larger Technion, and Rocket Research. We have joined with each after they have identified a problem in which the talents of CASP, UTSI or Calspan can be brought to bear in a specific problem in the propulsion arena. We have signed specific, product oriented agreements and contracts, each with deliverables and schedules and have lived up to and exceeded expectations in every instance.

In an endeavor to expand the opportunities of local business in commercial space we have teamed with Dr. Wu's Energy Research Consultants, Tesco, and Microcraft as they have pursued Small Business and Innovative Research topics. As you might be aware, Dr. Wu has recently received a Phase 1 SBIR. A Graduate Assistant who has worked with CASP for the past year and is now graduating, will join Dr. Wu as a principal investigator on this project. Such events are termed a success in our eyes. Not as significant as a pharmaceutical or life sciences breakthrough in which we edge closer to a cure for cancer, successes are somewhat less pronounced for CASP. If our code modifications lead to an increase in the efficiency of the Space Shuttle Main Engine which, in turn, allows additional payload to be placed in orbit, we are successful. If the diagnostic testing accomplished in the refurbished vacuum chamber allows a more efficient grid design for an ion engine, or the fluids transfer testing highlights a better method for injecting cryogens into orbiting spacecraft, we've been a success. CASP will most probably not make a first order impact in development of a multi thousand pound thrust chemical engine, we may permit greater efficiency but, most probably, our contribution will support development of efficiencies. We recognize that others will, most probably be the product innovators, we will provide systems to ease the transition from earth to space.

That brings me to my second topic, CASP's support to development of transportation and infrastructure. With the resources of both Calspan and the University offering great depth in space and missile testing and operations, CASP has offered to lead a transportation and infrastructure initiative for all the CCDSs.

In this initiative, we have suggested a method in which commercially oriented experiments and prototype hardware can be offloaded from the Shuttle and carried to orbit aboard a small expendable launch vehicle, perform their intended tests through the use of robotics or automated sequences, and be returned to earth in a recovery capsule.

The concept isn't new. Using 1960's technology, the Air Force successfully flew a large number (possibly over 1000) Discoverer missions in which ELV launched payloads were re-entered and recovered after their assignment was completed. NASA's BioSat missions, in which primates were successfully orbited and recovered by re-entering them in recovery modules after their mission in space was completed. Using the principles of the Discoverer and BioSat missions, we are suggesting that a system be put in place to service the needs of our commercial programs.

Launching on ELV's offers latitude in orbital parameters, allows carrying of industrial research material which might be considered inappropriate for the Shuttle, and, most importantly lets the experimenter define the duration of the flight, the type of data needed, and have immediate access to the experimental hardware after landing. Recognizing that such capability is being marketed actively by both China and Russia, we believed that development of such a competency within our country would fill a unique and marketable niche.

Market potential was quantified in a study completed by SAIC under a Lewis Research Center contract. SAIC surveyed all sources of commercial need for spaceflights between 1988 and 2000. The study concluded that more than 350 experiments are in the queue awaiting flight opportunities of some type. Many of these experiments will require multiple flights during the period and a full 1/3 of all experiments require recovery to ascertain the success of the process or hardware.

Before developing the concept the CCDSs were surveyed to specifically identify the needs of our commercial partners and investigators. The data indicated the same experiment weight distribution as the larger, all commercial, all country, all industry sample and gave credibility to the need for a recoverable system. Currently, only the CCDSs involved in development of earth sciences experiments desire to stay on orbit continuously. Having validated the SAIC sample, a group of CCDS members reviewed the existing U.S. capabilities in systems engineering, payload integration, launch vehicle & services, small satellites, and orbital operations which might be brought to bear on developing the entire spectrum of launch, orbital and recovery services. We elected to design and implement a system which could orbit and recover a small but usable volume of experiments; we believe that the developing large systems demands a schedule which would extend the first launch date well beyond our lifetimes.

We chose to suggest a COMmercial Experiment Transporter (COMET) program which would include a re-entry system which has a 2 cubic foot or greater payload volume into which will be placed commercial experiments. The re-entry system will be mated to a service module which includes the necessary telemetry, command and control, power, thermal, and attitude systems to support the re-entry system and its payload. Experiments which have no need of recovery would be mounted in the service module as well. When assembled, these two components become the FreeFlyer portion of the COMET system and would have a total, on-orbit weight of about 1000#. Such a system would be a proof of concept vehicle for the COMET program. Our FreeFlyer would be mated to a small expendable launch vehicle of the Pegasus class and launched from the Eastern Space and Missile Center into an orbit of 40 degree inclination. During its orbital lifetime, the FreeFlyer would be controlled from a commercial ground station and the contractor would provide experimenters either real time or recorded data, based on their needs and the orbital support plan.

At a pre-determined time and somewhere near the longitude of the Hawaiian islands, the FreeFlyer would be sent a command to begin its de-orbit sequence. Separating from the service module, the re-entry system would initiate retro-fire and the system would begin its decent into the White Sands Missile Range in New Mexico. At approximately 30,000 ft. a series of drogue, pilot and main parachutes would be deployed with the main chute being a fully controllable ram air or parasail design which would be flown to the landing beacon by an on-board receiver and control system.

Upon landing, the payload would be disassembled and the experiments provided to the investigators for their study. We intend for the re-entry system to be re-usable for a minimum of 5 flights with refurbishment costing in the vicinity of 20% of a new re-entry system.

Meanwhile, the experiments in the support module continue to function until the system burns up upon re-entry or the experiments have completed their mission.

Note that there are six major segments to COMET: re-entry system & services, launch vehicle & services, payload integration, the service module, and systems engineering. We intend for these functions to be accomplished by contractors. CCDSs are drafting statements of work and we intend to issue an RFP later this summer which will consist of six technical work statements.

The RFP will be structured such that a company may bid on any segment, combination of parts, or all six parts of the solicitation. We believe the efforts to be accomplished are suited to fledgling companies who can provide solid engineering and a streamlined management approach. For example, COMET requires a class of launch vehicle currently being marketed by Orbital Sciences, American Rocket, and Space Industries. Similarly, low cost ground stations, service modules (which are, in a sense, satellites) and orbital operations are all offered by companies whose future can be potentially tied to the success of COMET. Neither CCDSs nor their university counterparts will be allowed to propose since we are convinced that the secret of commercialization lies with commercializing the private sector, not the government or university systems. Simply stated, our overall goal in COMET is to develop an infrastructure. In its initial stage, CCDSs will accomplish conceptual design, structure RFP's, evaluate proposals and establish an Advisory Council, a Payload Selection Committee, and a Program Management team. We expect these CCDSs to perform technical monitoring and contract observation of the selected contractor's efforts. Each of the hardware and operations contracts will be tailored to the type of effort to be provided and structured to include performance incentives. Additionally, we believe it necessary to contract for multiple buys with options for additional units based on program needs. For example, we expect to fly the first three COMET "pathfinder" missions with 1000# total payload. We will therefore contract for three sets of hardware but retain options for additional buys. Since we expect to be working with "non aerospace giants" such an approach may allow smaller companies to obtain the capital needed for long lead parts procurement. We have a full complement of commercial payloads for the COMET launches.

Payload surveys indicate a market for a re-entry system with larger volume and weight carrying capability. We see a follow on to the 1000# pathfinder class as a re-entry system with a 10 to 15 cu ft payload volume and a total system weight of about 2200 lbs. With such a volume a larger number of experiments can be carried but, more importantly, larger, heavier, prototypes of space processing systems can be supported and placed into.

If we can project an outcome of the process, it would be the full commercialization of the COMET program. Commercialization will be achieved when one or more of the contractors has developed commercial ties and a market sense which leads them to assume fully, the costs of COMET operation. At that point, CCDSs leadership would be withdrawn and the commercial sector would be in a position to assume full responsibility for marketing, preparations, and operations. Our goal will have been accomplished: an infrastructure and supporting transportation hardware will have been developed.

In summary, the Center for Advanced Space Propulsion is accomplishing the goals set out for us: sustaining our country's dominance of the propulsion industry, in both current and future system development. In addition, we are uniquely qualified among the CCDSs to lead the development of the infrastructure and transportation elements necessary to support the commercial development of space.

Senator **Gore**. Of course, I am prone to be impressed by what you all are doing there. But I really am impressed and I think you have put the best foot forward here for Mr. Rose's program.

Before I recognize our final witness on this panel, Mrs. Lee-Miller, let me invite my colleagues who have arrived, if you have any introductory statements.

Senator **Bryan**. I have no statement, Mr. Chairman.

OPENING STATEMENT BY SENATOR PRESSLER

Senator **Pressler**. Mr. Chairman, I have a brief opening statement which I will place in the record. I apologize for being a bit late. I shall read the statements.

I want to thank you for holding the hearing today on the fiscal year 1991 budget request for NASA's Office of Commercial Programs and DOT's Office of Commercial Space Transportation. Space is the marketplace of the 1990s. There is every indication that it has explosive growth potential that marked semiconductors and computers in the 1980s.

Launch services, land remote sensing, communications satellite systems, and space-based materials processing all present fertile business opportunities. This reality is not lost on other countries.

Japan is working at a breakneck speed to build the H-2, a launch vehicle that should enable them to be a player in the fiercely competitive commercial launch industry. China is using its freedom from marketplace controls to set prices for launch services so low that no American company can hope to match them. France has turned its land remote sensing system into a commercially viable operation.

And as the number of spacefaring nations increases every year, the competition in the space marketplace grows even more intense. The United States cannot afford to be a bystander in the new space marketplace.

Mr. Chairman, I look forward to hearing these witnesses. I would say that NASA's Office of Commercial Programs is to be commended for establishing a consortia of private companies and universities which focus on cooperative research in technologies with commercial potential. This effort, along with NASA's technological transfer program should, facilitate the private sector's use of space.

Similarly, DOT's Office of Commercial Space Transportation plays an integral part in the licenses of domestic commercial launch services. This is one of the most promising of all the space-related businesses. I note that the fiscal year 1991 budget request for OCST is only 8 percent higher than the 1990 funding level. Given its importance to the safety and reliability of our domestic commercial launches, it is crucial that OCST receive adequate support in the budget.

I would also like to commend OCST for vigorously carrying out its statutory mandate of promoting the domestic commercial launch industry. Its voice has brought much needed attention to such policy matters as the proposed Australian spaceport and the questionable pricing practices of the Chinese launch industry. The resolution of these matters has long-term implications for the domestic industry.

Finally, I welcome the speakers on our second panel, the success stories in space business. It is their pioneering spirit that will blaze the trail for generations of space entrepreneurs. I look forward to hearing from our group of distinguished witnesses.

Senator GORE. Mrs. Stephanie Lee-Miller, Director of the Office of Commercial Space Transportation at DOT, returns for another appearance here. We are delighted to have you back, Mrs. Lee-Miller, and your statement has been placed in the record in full. Please proceed with a summary and we welcome your colleagues as well.

STATEMENT OF STEPHANIE LEE-MILLER, DIRECTOR, OFFICE OF COMMERCIAL SPACE TRANSPORTATION, DEPARTMENT OF TRANSPORTATION; ACCOMPANIED BY GERALD C. MUSARRA, PROGRAM COUNSEL; AND NORMAN C. BOWLES, ASSOCIATE DIRECTOR FOR LICENSING PROGRAMS

Mrs. LEE-MILLER. Thank you, Senator Gore. It is a pleasure to appear before this panel again. Certainly the support of the Senate is a very key feature to our policymaking and support for our industry as we strive to enter in and maintain a strong government-industry partnership.

So I certainly appreciate the opportunity to discuss our proposed fiscal year 1991 budget for DOT's Office of Commercial Space Transportation.

Earlier this year President Bush and Transportation Secretary Skinner unveiled the National Transportation Policy, a blueprint for devising a comprehensive strategy for setting our nation's future transportation goals, meeting our needs and keeping America economically strong and competitive. The newest transportation industry, commercial space transportation, was included as a significant feature of this policy.

When the President released the policy, in his remarks he indicated that we have a strategy to unleash the creative genius of American technology. This technology took us to the moon and now it must make travel into space economical and commonplace. This was a significant inclusion for us at the Department of Transportation because it recognizes commercial space transportation as the newest transportation sector, right alongside aviation, rail, and highways. So we certainly see it as a key feature of our competitiveness in the future.

With U.S. firms investing more than $600 million in the commercial space transportation industry and aggressively competing with the Europeans and other nations for leadership in the world commercial launch market, this new industry has made a promising start.

I do not think we can go too far in lauding and patting our industry on the back for their aggressiveness and their commitment to really trying to make the U.S. industry the leader in this new field.

OCST is proud to be playing a key role in building a new transportation infrastructure, a highway to space. Throughout history, technology has provided the inspiration and impetus for our progress as a nation. In much the same way as railroads were key to exploring and settling the west in the 1800s, commercial launch vehicles are essential to human exploration in space.

This new transit system will not only augment America's current civil and military space programs, it will provide the impetus for development of a robust space commerce industry. Clearly our industry cannot function in space and create the space commerce we are looking forward to if they cannot get to it. Access becomes very, very key.

Giving private entrepreneurs and customers a safe, reliable and cost-efficient way to transport payloads to and from space is a key objective of our office. I might say that, in transportation jargon, we want to begin to look upon our payloads as cargo and build a transportation industry that can effectively transport cargo to space, whatever that cargo might be.

Before I begin discussing the budget, I would like to take a few minutes just to note the progress of our companies and the industry because I think it is very key that we recognize that 1989 really represented our first year of actual licensing and implementing the Commercial Space Launch Act. To date, 5 successful licensed U.S. commercial launches have taken place. In addition, we released our manifest and our latest manifest shows 34 more launches expected to take place into the mid-1990s.

Now, our manifest represents contracts that are in place and completed. I know of, personally, an additional 20 or 30 launches that industry executives are telling me they expect will come, and our manifest does not reflect all of the launches that Jim Rose's operation will be bringing into the marketplace as well.

So we are looking forward to a dramatic increase, as more launch contracts are signed in the coming years. In 1991 we are hoping for and expecting as many as 40 commercial space launches.

Now all of these launches bring revenues, and the revenues that we can evaluate based on our current manifest are expected to exceed $1.7 billion. Any increase in these contracts certainly will be an increase in the revenues, and these revenues are all positive contributions to our economy. At a time when we are facing budget deficits, an industry that is growing and that can add to the economy as opposed to taking away from it becomes something worthy of all of our support.

Approximately $1.2 billion will be derived from non-U.S. Government sources. Foreign and international customers will contribute $900 million to this total. And given the price range of a single orbital launch, from $40 million to over $120 million, the benefit of each orbital commercial launch to our economy is significant.

This means jobs, technological advances in research and development, improvements in science and technical education, and a stronger, more diverse U.S. space program.

I often indicate that projects like the ones that Jim has and what we hear from industry could leap to something like the old days the gold rush. There is a lot of speculation and a lot of cynicism, but I am convinced that the first breakthrough, the first industrialist who figures out how to make money in space, will bring that rush is on. And we will see more and more market opportunities, more and more cargo going to space,and more and more private investment following that.

I would like to talk about our budget, and I will summarize the money that you appropriate to us and what those monies will go to cover. We have primary responsibility within the Office of Commercial Space Transportation for regulation of this industry, as well as its promotion, and also for facilitating the industry where feasible and possible.

This main feature of our regulatory authority certainly includes research on safety as a primary objective. We also conduct market analysis, and we participate very actively in the policymaking process. Senator Pressler, I want to thank you for your remarks and your comments about recognizing that we at OCST are very active in the policymaking process and very aggressive about expressing our views.

We are requesting $3.1 million for research in safety contracts, and I am not going to go through all these dollars but I will hit the high points for what this will include.

It is very important for us to provide effective regulatory guidance for commercial launch activities, and this is dependent on timely, thorough research on safety issues. Our research studies are essential to creating and maintaining a new data base that is adapted to this unique industry. We do not want to rely on old material in how we evaluate the needs of this industry. We must create a primary research base that can respond to the problems unique to commercial space activity.

So we are concentrating on building a solid regulatory program that is not available from other government sources. At OCST we want to be and will be the custodian and repository of all the current information regarding research in safety in commercial space.

Now this will include research on commercial launch operations and range activity. As our industry grows, it will develop new launch activities, and new payloads will develop to meet future market demand. There are foreign proposals that we are hearing about all over the place to establish new spaceport facilities in other parts of the world. So we have to ask the question, which we are doing, are our current launch sites able to accommodate future commercial launch activities?

In order for us to address this question, we must study existing site conditions, launch operation procedures, personnel certification, and equipment and design requirements. These study findings will be used as the criteria to regulate and provide licensing for future U.S. commercial launch sites and to review safety procedures, launch activities and personnel.

In the short run, we must have this data to evaluate the safety of our existing launch facilities. The facilities we have now were designed to support government operations, and bringing the commercial operations into these facilities has certainly created profound change in the role of the ranges and the launch operator.

The Air Force, in particular, has been impacted because it manages the ranges, and the Air Force deserves to be commended, as it has sought to accommodate the needs of the commercial customer. However, this has brought about change and all of it has not been easy. All of it has not been smooth. But we are continuing to work together to smooth out and streamline these processes.

We are going to conduct, and are conducting research on payload safety. New technology will come into the marketplace. You heard earlier about our expectation that reentry vehicles are going to be the next wave of getting into space and being able to re-enter back into our environment with experiments conducted successfully.

As new technology is introduced into the marketplace, new payloads will be developed, and we must review all of these matters to make sure they meet appropriate safety standards.

We will be conducting continued research into personnel qualifications and certification, a very critical area, of safety procedures. Safety equipment will be included in our review. Equipment design and reliability is a fundamental element in protecting public safety and property.

We will also be looking into environmental safety. As we review license applications coming in for commercial spaceports, environmental considerations become very key to the citizens in those areas, so we in fact are involved in conducting an environmental impact study with the State of Hawaii at this time.

Orbital safety becomes a key area for us, safety standards, including assessing on-orbit and re-entry hazards to commercial launch vehicles.

Space safety support and management, is an internal function designed to implement our computer system software and hardware so that we can track our licensing activities and develop performance measures to analyze flights and risk models for future launches.

Continuing licensing and enforcement operations. Prior to each launch we send out an inspection team that reviews the safety procedures of the launch operator. We also must have resources in order to conduct any potential accident investigations. That is our responsibility.

OCST is also tracking and maintaining information on the capabilities, market developments and competitiveness of commercial launch providers and customers. We get many requests for this data, and we are developing a data base which will track worldwide systems. What the competition is doing, what kinds of vehicles they are developing, what the pricing of those vehicles are, reliability, physical characteristics of existing and projected launch vehicles are included in that as well.

We are also spending considerable time developing policy analysis and responses to requests coming in, working with the National Space Council, as well as the very active interagency process.

We have a very important priority of responding to industry requests for information on its activities. We maintain an excellent industry advisory committee at DOT called the COMSTAC, and it is populated by senior executives of all of the primary launch companies at this time, as well as satellite operators. So we support that function and it becomes a very strategic way for us to solicit from industry their views, their needs so that they can be incorporated as a key feature of any public policymaking that is going on on a range of issues.

Of course, in support of all of this activity there is tremendous demand from the space community that the Office of Commercial Space Transportation be present at many, many conferences, both domestically and worldwide, so the funds that you appropriate to us do allow us to provide information both within the current demand domestically and at conferences abroad. There is tremendous public interest in commercial space, and that requires us to participate, provide technical data and be present at meetings, both domestically and to carry the U.S. flag into international forums, where appropriate and necessary.

And, finally, the budget request includes whatever expenses are needed for our personnel compensation and benefits. We are a small office. We have 24 full-time employees who will be covered in this request. The number of employees that we have, frankly, does not really keep pace with the demand that we are anticipating so we will be continuing to request, I am sure, increases in our budget in coming years and will welcome the support of the Senate in accomplishing that.

To conclude my testimony, Mr. Chairman, let me say that the Department is very pleased by the progress of the growing commercial space transportation industry. I know that you are a champion of this industry, and that support is very key and appreciated by the agencies as well as by the industry.

We are facing many exciting years to follow. It is going to be tough. We cannot afford to make any mistakes. We are very steadfast, Secretary Skinner is, and the team at DOT in support of the commercial space industry. So thank you for this opportunity to address the Subcommittee.

[The following information was subsequently received for the record:]

Responses to Chairman Gore's Written Questions
Follow-up to FY 1991 Budget Authorization Hearing
Senate Committee on Commerce, Science and Transportation
Subcommittee on Science, Technology and Space

From Stephanie Lee-Miller
Director, Office of Commercial Space Transportation
U.S. Department of Transportation

Federal Support for U.S. Launch Industry

QUESTION 1: The Federal government has always played a role in the launch vehicle industry in this country.

- What actions are being considered within DOT and the Administration to help U.S. launch firms respond to the challenges of the 1990's?
- How are the technology programs advocated by the Administration likely to help U.S. competitiveness in the coming decade? For example, can ALS be developed and put into service without creating a single U.S. quasi-public national launch company?

ANSWER 1: DOT, as a participant in the Administration's space launch review, will examine ways to provide an environment in which the U.S. launch industry can respond to the challenges of the 1990s. These areas range from international trade to domestic procurement of launch services. All segments of the industry are being addressed, from payload and launch vehicle technology programs to support infrastructure.

Government and private sector technology programs are both important elements of the long-term future of the U.S. launch industry. One cannot assume that a program like ALS will result in a single, highly efficient vehicle and a sole launch company to build it based on federal support.

U.S. Launch Facilities

QUESTION 2: Recently, the Director of the Eastern Test Range -- including Cape Kennedy, the Air Force, and commercial facilities -- indicated that launch facilities and launch crews are hard pressed to meet current schedules.

- Is there an overload at the east coast launch facility? If so, how will it affect the competitiveness of U.S. launch companies now and in the future?
- What is the status of activities to develop commercial space launch facilities in Florida, Hawaii, Texas, and Virginia
- In your view, does the domestic ELV industry require a commercial launch facility?

ANSWER 2: At this time, the issues of facility availability and competitiveness and the needs of the domestic ELV industry are under consideration by the National Space Council's Launch Strategy Review. However, it is inappropriate to speculate or comment on the Council's possible policy recommendations at this time.

Several states are addressing the infrastructure issue by exploring the feasibility of developing commercial launch facilities. For example, Florida has created a Spaceport Authority and approved $500 million in bonding authority to support its development. Hawaii has selected two potential launch sites, located at Palima Point and Kahilipali Point on the coast of the main Island. In addition, Texas and Virginia are exploring commercial launch site concepts.

Responses to Sen. Inouye's Written Questions
Follow-up to FY 1991 Budget Authorization Hearing
Senate Committee on Commerce, Science and Transportation
Subcommittee on Science, Technology and Space

From Stephanie Lee-Miller
Director, Office of Commercial Space Transportation
U.S. Department of Transportation

QUESTION 1: In 1980, the U.S. had 100 percent of the commercial space launch business. What percentage do we have now?

ANSWER 1: The U.S. commercial launch companies currently have firm contracts for 25 orbital payloads, which is approximately 36 percent of the 68 orbital payloads currently listed on commercial launch manifests.

QUESTION 2: What is your projection for how that percentage will change over time? What are the reasons for the change?

ANSWER 2: We expect the U.S. to win approximately 50% of the market over the next several years; however, the entry of new launch services providers as well as other changes in the market could adversely affect the market status of the U.S. commercial space launch industry.

The PRC and the Soviet Union are attempting to gain footholds in the world launch market. The Soviet Union is seeking to enter the market through the sale of launch vehicles to other countries. Such activities, if not priced in accordance with free and fair trade principles could undermine U.S. and European commercial services.

Also, changes in infrastructure would affect the ability of commercial launch companies to meet customer demands. The National Space Council is currently studying national launches and infrastructure requirements.

QUESTION 3: I understand from NASA testimony last year that the Japanese have now taken a majority of the market for communications equipment for satellite ground stations. Is that correct? How has the U.S. market share for that equipment changed over the last decade?

ANSWER 3: OCST is not generally involved in matters related to satellite ground stations, and we currently have no information on the market share for that sector. We suggest that you contact the Department of Commerce for that information.

QUESTION 4: Will the decision on the United Technologies application to manage the proposed Cape York spaceport come after the National Space Council issues its recommendations for a national space policy? Is the National Space Council expected to meet its June 1 target date for completion of their work?

ANSWER 4: The application of USBI, United Technologies, Inc.'s subsidiary, for approval of its Technical Assistance Agreement is currently under review at the senior U.S. government policy level. A decision is expected in the near future. Since no decision has yet been made, it would be inappropriate to comment further at this time.

QUESTION 5a: What is your estimate of the amount (as a percent) by which the French are subsidizing launches on their Arianespace missile?

QUESTION 5b: What is your estimate of the amount (as a percent) by which the Chinese are subsidizing satellites launches on their Long March missile?

QUESTION 5c: What is your estimate for the Soviet's subsidies (as a percent)?

ANSWERS 5a, 5b, and 5c:

We currently have only limited information on cost and price structures for Europe, the PRC and the Soviet Union. In the case of non-market economies, the concept of subsidies does not apply, since the extent of "subsidies" cannot be determined definitely.

QUESTION 5d: In his speech, Vice President Quayle also recognized the very high initial investments that are often needed in the space business. Where these high initial investments form barriers to new markets, the Vice President said, "In such cases, the government must take positive actions." What kind of "positive actions" did the Vice President mean?

ANSWER 5d: These matters are currently under review by the National Space Council, and its conclusions will be made public in the near future.

QUESTION 5e: The news account in "Communications Daily" of the Vice President's speech said that "We are told..." his speech may indicate a shift in policy toward "indirect support along such lines as funding launch facilities and other infrastructure elements that could be used by civil, commercial and military groups." Is such indirect support currently under serious consideration?

ANSWER 5e: The National Space Council is reviewing the infrastructure issue as part of several national policy strategy studies. As this review is in progress, it would be premature to comment on any specific actions.

QUESTION 6: In May 1989, you issued a report entitled, "Scheduling Commercial Launch Operations at National Ranges," which concluded, "The limited number of launch pads is currently the most significant factor that constrains the availability of launch dates and the ability of launch ranges to maintain schedules."

In your testimony of May 15, 1990, you indicate that 34 more U.S. commercial launches are now expected to take place well into the mid-1990s. You indicate that the manifest is expected to grow dramatically".

Doesn't this suggest that the limited number of launch pads in the U.S. for commercial space launches is even more of a problem today than it was a year ago? Are the national ranges expected to satisfy the new demand?

ANSWER 6: The issue of U.S. space launch infrastructure is being addressed by the National Space Council's Launch Strategy Review. However, it would be premature to speculate or comment on the Council's possible policy recommendations.

QUESTION 7a: Your report of May, 1989, also concluded that there was a need for "additional study of the U.S. space launch infrastructure" and that,

> A commitment by government or industry to build more launch capacity at the national ranges, at ranges operated by the states, or at commercial spaceports is highly significant from a commercial view point, as it would reassure payload customers that the U.S. space launch industry will have the facilities necessary to meet their needs.

How is that additional study of U.S. space launch infrastructure being conducted? In your statement of May 15, 1990, you indicated that OCST is addressing the question of whether our present launch sites will be able to accommodate future commercial launch activities. When do you anticipate you will complete your study?

ANSWER 7a: DOT is working concurrently with the National Space Council and independently to address the infrastructure issue. At this point in our studies, we are still examining the issues and options involved. While a definitive completion date is still uncertain, the studies are progressing at a rate which allows DOT to maximize its input in the National Space Council efforts. With the impacts this issue has on commercial industry, DOT has been taking a strong position to ensure that it is addressed in this national forum in a thorough manner.

QUESTION 7b: Your report of May, 1989, also concluded that there was a need for "additional study of the U.S. space launch infrastructure" and that,

> A commitment by government or industry to build more launch capacity at the national ranges, at ranges operated by the states, or at commercial spaceports is highly significant from a commercial viewpoint, as it would reassure payload customers that the U.S. space launch industry will have the facilities necessary to meet their needs.

Is that additional study being conducted by the National Space Council as well? If so, do you expect that the policy recommendations of the National Space Council will address whether there are enough launch pads in the U.S.?

ANSWER 7b: As indicated in response to a similar question, Question 6, the issue of U.S. space launch infrastructure is being addressed by the National Space Council's Launch Strategy Review and we feel that it would be inappropriate to speculate or comment on the Council's possible policy recommendations at this time.

QUESTION 7c: Can we anticipate that the National Space Council study will indicate how we can provide reassurance to payload customers that the U.S. space launch industry will have the facilities necessary to meet their needs?

ANSWER 7c: The issues of accessibility and availability of facilities and the needs of the payload customer will be addressed by the Launch Strategy Review.

QUESTION 8: Are you currently considering sites within the U.S. in your evaluation of potential commercial launch sites for the future? If so, which ones?

ANSWER 8: We are examining all sites that can best promote our commercial space launch industry. Launch sites in Florida and Hawaii have been particularly visible because these states have progressed the furthest in developing their concepts. However, the study has been structured to leave opportunities open for newer concepts that may materialize during or after the study and we hope to encourage further efforts.

QUESTION 9: To what extent do you think the development of "lightsats" will spur the demand for satellites and launch services in the future? In a report entitled, "An Assessment of Potential Markets for Small Satellites," three authors from George Mason University conclude,

> In summary, pushed by DARPA, Navy, Air Force activities as well as by government budgetary constraints, small satellite capabilities are being put in place which will provide the industry with the capability to aggressively seek new markets at a time when new contracts for large satellites may be diminishing, or becoming less profitable and more competitive.

ANSWER 9: After 3-4 years of development, small launch vehicles and small satellite technology have begun to emerge as a prominent trend in space. These capabilities offer unique flexibility and resilience. The potential benefits of these technologies are already accepted by several governmental agencies.

At least 16 "lightsats" have been launched this year. And, within the last 3 months, several companies have announced their intent to launch over 100 lightsats to low earth orbit over the next 6 years. Because these new concepts not only open opportunities in technology but also challenge the traditional concept of utilizing space, it is difficult to estimate the growth potential of the demand for launch services.

These developments do, however, suggest there may be a potentially significant new market area that could greatly benefit the new smaller vehicle entrants to the industry.

QUESTION 10: What role will USDOT assume in range safety at a new commercial launch facility? Would USDOT's role be solely as a regulator, or might USDOT also provide equipment and personnel for this function such as is the case with air traffic control?

ANSWER 10: The issuance of a commercial site operator's license by DOT will be based on DOT's evaluation of a site operator's ability to ensure public safety and the safety of property. Applicants will be required to submit material demonstrating the applicant's understanding of the safety issues involved and how to minimize potential hazards. This material would include, but not be limited to, a discussion of personnel qualifications, organization, safety equipment, etc. After a license is issued, DOT must be informed by the operator of any proposed changes which would alter the operations covered by the license.

DOT does not see itself in the role of being a supplier of equipment and personnel, as is the case with air traffic control. Equipment and personnel will be provided by the site operator.

QUESTION 11: USDOT/OCST must license commercial launch operations. What regulatory guidance and policy directions are available? What is being planned?

ANSWER 11: OCST has published regulations providing the procedural framework for licensing commercial launch operations (Title 14, CFR, Parts 400 through 415). OCST is currently in the process of updating its regulations and guidelines. OCST has also published other reports and papers which provide guidance and directions for prospective launch companies, site operators and others interested in commercial space. Examples include environmental assessment studies, range baseline assessments, hazard analyses, and orbital debris studies.

Responses to Sen. Pressler's Written Questions
Follow-up to FY 1991 Budget Authorization Hearing
Senate Committee on Commerce, Science and Transportation
Subcommittee on Science, Technology and Space

From Stephanie Lee-Miller
Director, Office of Commercial Space Transportation
U.S. Department of Transportation

QUESTION 1: Currently, international launch companies compete for about 20 new commercial contracts per year. How many companies can such a small market reasonably sustain? Who are the current commercial launch competitors? Are there any new entrants on the horizon?

ANSWER 1: At present, the major competitors in the medium to large payload market are three U.S. firms and the Arianespace consortium. The award of new launch contracts in 1989 and 1990 has resulted in 18 additional payloads for Arianespace and 14 additional payloads for U.S. firms, with awards approximately split in 1989 but with Arianespace having more success than the U.S. companies so far in 1990. Moreover, due to Arianespace's greater presence in earlier years, it leads in terms of outstanding launch contracts. In total, U.S. commercial launch firms have outstanding contracts to launch 24 orbital payloads, whereas Arianespace has outstanding contracts for 39 orbital payloads.

Several U.S. aerospace firms offer commercial launch services. McDonnell Douglas Space Systems Co., Martin Marietta Commercial Titan, Inc., and General Dynamics Commercial Launch Services, Inc. are large, established firms that offer orbital launch services for medium to large payloads. In addition, some small entrepreneurial firms are seeking and/or have won contracts to conduct launches. These companies include Space Services Inc. of America, based in Texas; Conatec Inc., located in Maryland; the Orbital Sciences Corp. of Virginia and its subsidiary, Space Data Corp.; and E'Prime Aerospace Corp. of Florida. These companies offer small orbital and/or suborbital launch services.

In the international arena, the People's Republic of China (PRC) has been marketing launch services since 1984 and currently holds three firm commercial launch contracts. On April 7, 1990, the PRC successfully completed its first commercial launch. The Soviet Union is also marketing launch services, although it has not yet won any contracts to launch Western-built satellites. The Soviet Union is also discussing with Australia the possibility of selling vehicles for launch from Cape York beginning in 1995.

Europe's Arianespace, which operates the Ariane 4 vehicle family, is actively developing the Ariane 5 rocket, which will represent a significant improvement in lift capability, cost efficiency, and technology relative to the Ariane 4. This vehicle is scheduled to be test flown in 1995, and to begin commercial deployment thereafter. All Arianespace launches are planned to occur on the Ariane 5 after 1998. Satellites launched by small vehicles are not included in the market you described above in your question.

Japan's National Space Development Agency is developing its latest launch vehicle, the H-2 rocket. This rocket will have the capacity to place a two-ton payload into geostationary orbit. As such, its lift capacity will be similar to those of the European Ariane 4 and the U.S. Titan III. The H-2 is considered a good bet for entry into the world commercial launch market sometime after 1993.

The emergence of new launch services providers in the next decade will be a considerable challenge for U.S. companies. Moreover, the presence of highly subsidized and non-market competitors could put U.S. companies at a particular disadvantage.

QUESTION 2: What effect will the planned Australian spaceport have on the U.S. commercial launch industry? What is the status of the export launch license application filed by United Technologies to permit its involvement with the project? Will the spaceport's use of Soviet rockets pose any technology transfer risks?

ANSWER 2: The Cape York Space Agency (CYSA) of Australia is proposing to launch Soviet-made rockets from a site on the east coast of the Cape York Peninsula in northeast Australia. The U.S. firm of USBI, a subsidiary of United Technologies, Inc., is currently seeking an export license from the U.S. Government that would permit it to engage in technical discussions to provide design and development services to CYSA. We understand that the company eventually plans to seek further export licenses to permit it to act as project manager for the Cape York Spaceport. Current proposals call for facility construction to begin in 1992 and be completed in 1995.

The application of USBI for approval of its Technical Assistance Agreement is currently under review at the senior U.S. Government policy level. Since no decision has yet been made, it would be inappropriate to comment on the potential impact of the decision. However, we would note that questions relating to technology transfer and nonproliferation, as well as commercial implications of the proposed U.S. company's participation in the Cape York Spaceport, are being taken into consideration in the course of this review. A decision is expected in the near future.

QUESTION 3: The Department of Transportation (DOT) and the National Aeronautics and Space Administration (NASA) are currently disputing the authority of DOT to license commercial launches of NASA payloads. Would you describe the agencies' positions in this debate and the status of this dialogue?

ANSWER 3: Congress has authorized DOT to license U.S. commercial launches under the provisions of the Commercial Space Launch Act of 1984. The National Space Policy directs DOT to promote and license commercial launch operations that support civil government activities. Our intent is to simplify the federal regulatory requirements which must be met by prospective commercial launch services providers. In this objective, the Administration as a whole intends to fulfill the purposes of both the Act and the Space Policy, and both DOT and NASA are active in assuring this outcome.

QUESTION 4: How can U.S. commercial launch companies effectively compete against companies that are heavily subsidized or are part of non-market economies?

ANSWER 4: The entry of subsidized or non-market providers into the world marketplace presents a critical challenge to U.S. space launch providers, especially if they compete unfairly. U.S. commercial launch companies will not be able to compete effectively against non-market or heavily subsidized foreign operators unless free and fair trade principles are established to moderate the actions of these operators. Consequently, the U.S., through an interagency process coordinated by the U.S. Trade Representative, is formulating a strategy for developing such rules of conduct.

Senator **Gore**: We thank you very much. We appreciate your statement.

We are going to use the clock this morning. Senator Pressler has to leave early, so I will yield my first amount of time to him and then recognize Senator Robb.

Senator **Pressler**. Mr. Chairman, thank you very much. I have just one or two questions. We are having a markup over in Banking, plus I have some airline problems in my state on which we are having a meeting.

I would like to ask Ms. Lee-Miller what effect will the planned Australian spaceport have on the U.S. commercial launch industry? What is the status of the export license application filed by United Technologies to clear the way for its involvement with the project? Will the spaceport's use of Soviet rockets pose any technology transfer risks?

Mrs. **Lee-Miller**. The issue generally referred to as Cape York has been a primary concern of mine for some months now. Let me answer the second part of your question first in terms of the status of the application.

The decision on the application that United Technologies sent to the State Department was reviewed through interagency coordination. It was my office that in the review of that application raised some fundamental questions about the importance of the impact of Cape York on the industry worldwide, and it has thus gone into an extensive interagency review process. Currently, the decision is at the White House for final decisionmaking at the Space Council level, at the highest level of the White House.

I cannot give you the final determination that will come out from the administration on that particular request; however, I will give you the DOT view.

The entry of the Soviet vehicles that are proposed for Cape York in Australia present a real concern to us at the Department of Transportation because, of course, we are the agency tasked by the Congress to look out for the needs of the industry.

Australia is proposing to bring in the Soviet vehicle at a cost of $20 million, which undercuts anything that western launchers are able to bring into the marketplace. This would include Europeans as well as Americans, but, of course, our concern is the U.S. launch companies.

We think that to have the U.S. industry compelled to compete with a government-created launch capacity, because the Soviet launchers were built by the Soviet Union government, presents an unfair competitive situation for the transportation industry. So we have been expressing our view within a very open and vigorous—and I must stress that this process of decisionmaking that is taking place at the Space Council is really working very, very well. It is a very vigorous process. The agencies are given an opportunity to be very frank and up front about what they consider the issues to be.

We have expressed our concern on the economic impact. Commercial space transportation is viewed by DOT as a strategic industry, strategic to our defense. We also view it as an industry that has features very key to our economic competitiveness, as I indicated earlier, the contribution to the national revenue. So we are expressing our views; of course, it is not our decision to make.

We are dealing with a new reality in the world right now in the international marketplace with all that is going on in the geopolitical situation. So we are submitting our view, but we cannot predict what the outcome will be. Whatever it is, of course, we will implement.

Senator PRESSLER. Mr. Chairman, I will submit the rest of my questions to all the witnesses for the record. I hope to be back. I have to go to the Banking Committee for a markup.

Senator Gore: Thank you, Senator Pressler. Let me comment briefly on your last response. If I might, Ms. Lee-Miller, I want to congratulate you for the articulate way in which you just expressed your department's position on this matter. I urge the White House to listen very carefully to the concerns you have expressed. As you may know, I have been active in expressing similar concerns.

It is quite understandable that United Technologies would be enthusiastic about this venture. It is understandable that the Australians and the Soviets would be enthusiastic about it. But for the life of me, I cannot understand why the United States of America would be enthusiastic about it as a whole because it does, as you say, completely undermine the principle of free competition and any chance on the part of the U.S. launch companies to compete. This is a development which really should receive close scrutiny.

As far as I can tell, the State Department is the only executive branch agency in favor of the Cape York proposal, and I hope that your view prevails. I salute you for your vigor in expressing it here this morning. Sometimes agency or department spokesmen are a little cautious when something is residing in the White House for a decision. I prefer candor. I think that you have used candor this morning, and I appreciate it.

Senator PRESSLER. Just a footnote. I would join in those remarks.

Do you have a feel for reaching a consensus with the White House? How far has it come along?

Mrs. LEE-MILLER. Well, there has been extensive discussion, as I have indicated. The National Space Council is conducting an expedited policy review right now. We are engaged in reviewing and putting into place a policy framework which can really address the issue in a broad sense of many, many factors, both domestic and global, that affect this industry.

I expect, at the Vice President's direction, that the National Space Policy deliberations will occur sometime in early summer, and based on that, specific decisions of this nature will be hopefully easier to make in the future. There is a vigorous debate, as I indicated.

The entry of nonmarket economies into the marketplace presents a real challenge for the United States. While we certainly want to support and cooperate internationally because we have many space objectives where international cooperation is very key, also the Australians are our allies and we support their goal to be active in space.

Senator GORE. The Soviets may soon be, also.

Mrs. LEE-MILLER. Well, yes. So I want to stress that, as I indicated, we are parochial at DOT, admittedly, and our parochial view has to be taken that way. We are dealing in the administration with a new reality, taking into account many factors that certainly we at DOT are not responsible for adjudicating, so we cannot predict the outcome; but I do expect that during the summer we should have some resolution of this issue at this time.

I do not by my candor intend to be preempting any White House decisionmaking on this matter and do not intend to convey that.

Senator GORE. I will tell Mr. Sununu that, lest he misunderstand that point.

Mrs. LEE-MILLER. I would appreciate that.

Senator GORE. Senator Robb, if you will allow me just one followup question on this because it flows therefrom.

Senator ROBB. Of course.

Senator GORE. It seems to me that what is needed is an international set of rules of the road so that we can have, if not the proverbial level playing field, which I do not think ever really exists, something approximating it. Then countries would show appropriate forbearance in stimulating competition on the basis of cost, efficiency and competitive behavior rather than allowing a spillover from command economies that have not yet completed the transition, a spillover from military budget overhangs that result in surplus EOBs, but instead take a longer view that recognizes the larger importance of sensible rules of the road that promote competition.

We have been consulting with Europeans, in particular but all of the spacefaring nations on rules of the road for international trade and commercial launch services. I think it is in our interest to work them out.

Could you tell us briefly the status of these consultations?

Mrs. LEE-MILLER. Senator, the rules of the road are important. The view I entered the discussion of rules of the road with is we are not ahead in worldwide competition. Because the U.S. is not ahead in commercial space right now, the question becomes what do we gain from the discussions.

Now at this point I think we will be entering into discussions with ESA in the coming months, from what I understand. Of course, it is the U.S. Trade Representative's Office that has the responsibility for this, and we do expect that there will be a continuation of negotiations fairly soon.

As we enter the negotiations, I think it is important for the United States to have something that we want to come out of these negotiations with. We are concerned about the various levels of support that other governments give to their industry. The U.S. Government is not providing the level of subsidy and support and assistance as are other governments, so we are not interested in walking away from these negotiations having traded away anything.

So as we approach these, from my vantagepoint, with some caution, negotiating rules with your competitor when he is ahead should be done very carefully. That is the way we are looking at it from the transportation view.

Having said that, however, it is clear that with the nonmarket economies entering in to the world commercial lauch market we do need to establish some understandings with our friends, the Europeans and the Japanese, if they come in, because they are market-based economies. To the extent that we can establish understandings and principles in the marketplace with people who operate the way we do, that cannot but help us in the long run. Then perhaps together we can begin to address how we include and encourage the nonmarket economies to operate in a more commercial manner.

So there are some objectives that we can gain; but again, I think we should not rush into it.

Senator GORE. Very good.

Senator Robb.

Senator ROBB. Thank you, Mr. Chairman.

Just a brief question if I could for Mr. Rose. As I think everyone is aware at this point, we may be about to have a brief visitation by something called fiscal sanity. It may be only a cameo walk-on appearance here in the Nation's Capital, but there is at least a budget summit which is reporting to me today to discuss some very real challenges in that area.

Like the Chairman and others on this committee, I am very much interested in the commercial opportunities in space. As a matter of fact, I hope I will be able to stick around for a minute. I have a more than passing and specific parochial interest in one of the witnesses on the next panel in that particular capacity.

Having said that, when we are talking about an increase in budget, particularly given the fact that we are acknowledging that Japan, Europe and others of our competitors, the Soviet Union, are largely doing it as a government-sponsored program and we are doing it by trying to encourage the private and commercial applications of space technology, how would we respond in a way that would be useful to you and to your budget request in the austerity environment in which we are currently operating with a request for essentially doubling your budget?

Mr. ROSE. As I was saying, Senator, before you got here, we have reached the point in the program that we have set up to try to develop with industry the centers for the commercial development of space, the technologies that will lead to developments by the private sector into real applications that will ultimately meet the challenge of getting American industry first into reaping the commercial benefits from space.

The reason our budget has significantly gone up this year is that in order to carry out the flight test segment of that program, in order to get the technologies under the belt in some 61 areas, we have begun to initiate an ELV program in which the State of Virginia is quite interested, and that Joe Pawlick here with our center in Telehoma, Tennessee is going to help to develop the infrastructure commercially to carry this out.

We need to lease a commercially provided facility to augment the shuttle's mid-deck in order to carry out the necessary experiments in the time frame. So we have reached a point in the program that in order to carry the program out in a timely manner we need this type of increase.

Now the type of moneys we are talking about, I guess the whole OCP budget is less than six-tenths of 1 percent of the NASA budget. So it depends if we take a general cut like everybody else from a percentage basis.

We are a leveraged program. In other words, industry is contributing about $3 to every one we put in; therefore, if we lose part of this budget we will extend the program out, we will lose industry support, and we will lose their interest. So unlike a lot of programs where you just simply stretch it out and delay it a year, if we delay we are going to lose a lot of the momentum and enthusiasm that is beginning to develop by a private sector.

So the moneys are not large, even though it is a doubling.

Senator ROBB. I do not disagree with you in terms of the magnitude of the numbers about which we are talking, but we are obviously in an environment where everybody is going to be looking at every single expenditure.

This is the question that no one ever likes to ask, particularly before you have exhausted all other possible remedies. Are there areas other than simply cutting back across the board on the leveraging of each of the projects to which you referred where some cost could be saved, some savings could be achieved if push really comes to shove?

Perhaps I ought to ask it this way. What would be the impact or the effect of someone coming back and with a very sharp pencil putting you back just about where you were and saying what can you do for this amount of money?

I am not suggesting that as an approach. As a matter of fact, I am very much interested in finding areas within the whole budget process where we can clearly make some positive contribution and not simply continue to fund what may be a less desirable program or initiative, whatever the case may be.

How would you arm those of us who want to see some of this commercialization continue in terms of the question I asked here? What can you give up or what are the consequences if you hold the line in the absolute sense?

Mr. ROSE. What we would give up—and I believe the way it would have to be is this, we have a program where we have 61 different technologies that are under development by these centers. In order to carry out the work in those 16 centers and in those technology fields, we need a certain amount of capability to support a flight program to get the database that we need. If we have to cut—obviously you have to have a balance between transportation and what it takes to test them and the number of things you want to test.

So when you make a cut, what you will probably end up doing is to actually eliminate some of the activities in the centers or even eliminate some centers if it makes more sense to maintain on a priority basis those things that you feel are the most important to carry out in order to balance a flight program with something that is worthwhile carrying out in the way of a technology base.

Now we have selected these technologies fairly carefully. They have been screened. And we think they are all good and all offer promise, and we have a balanced program. But obviously, the way I think we would handle that is simply we would have to eliminate parts of the program so that we can keep—those that are still there can have the flight opportunities they need, or else they will leave us, too.

You cannot just cut transportation—you just cannot cut technology. You will have to go in and do some surgery.

Senator ROBB. Are there any areas that you can—and again this would not be a welcome question, I recognize that, but it is the type of battles we are going to ultimately have to fight, so we might as well put any affirmative responses on the record—are there any areas where specific private sector participants would be willing to increase the amount of money that they are putting into the leverage equation?

Mr. ROSE. We have been continually growing in industry's participation on a leveraged basis. I think we have gone up another 7 or 8 percent between last year and this year in industry's contribution compared to the government's in the program. It is a continuing growth thing. How fast they will grow depends upon how well we are going to carry out the programs that they are interested in.

So I think the answer to your question is we are trying to leverage as much as we can right now. I cannot guarantee you that anybody will step to the alter if we reduce funding here. They will look at that as being a negative. They will say the government really is not interested. We do that periodically with the industry.

Senator ROBB. Thank you, Mr. Rose. As I say, I am sympathetic. Mr. Chairman.

Senator GORE. Thank you, Senator Robb.

And I, too, am sympathetic. And Senator Robb and I both know David Thompson on the next panel, who is going to be telling us of their exciting success.

Is it fair to say that you have a lot of competition for the awards you make for the participation that you have?

Mr. ROSE. Oh, yes. I think the original—there were three competitions held to reach the 16 centers that we have. And in each case I think there were over 30 proposals, where five were selected in the first go-round, some four in the second go-round, and seven or more in the last go-round. If that is what you mean.

Senator GORE. So how many out of the 30 total were granted?

Mr. ROSE. To the first group of 30 there were five selected. That was in 1986. In 1987 there were another four; that is nine.

Senator GORE. Were there more applicants?

Mr. ROSE. Thirty more new proposals came in.

Senator GORE. Okay.

Mr. ROSE. And then there was a third series of proposals, again, with 30 some companies. And each time there were one or two more companies by count than the previous one. And so seven were selected in the last go-round. That makes up the 16.

Senator GORE. So for each winner you have got about five or six or seven competing applicants for that designation?

Mr. ROSE. That is correct.

Senator GORE. That, it seems to me, is a real good indication of a healthy program. You are getting a lot of competition. You are stimulating a lot of competition by small teams, with interesting and innovating ideas. That is really health.

And most of the increase that you are talking about here is for the new launch opportunity that will expand your ability to stimulate that competition and to make it attractive.

Mr. ROSE. No question. We are trying to kill two birds with one stone. We need the transportation in order to support the technologies for the centers. By the same token, we want to also invigorate the new transportation entrepreneurs out there, such as David Thompson and many others who visualize commercial transportation of the future as maybe something different than those transportation systems we are now flying for the communications satellite world.

Senator GORE. Well, the success of a company like Orbital Sciences and others that might get into this kind of launch business would be greatly affected by the extent to which you are successful in promoting a lot of competition from small payload companies that want to run experiments and want to do applications in space but do not want to necessarily borrow the money to book up space on the space shuttle. They want a small, cheap orbit that will let them do their small, effective mission.

And so if you are successful, then small launch companies are apt to be more successful, too.

Mr. ROSE. We believe that. And we believe that not necessarily everything in the future that is going to be commercial is going to be large. We think the trend is going to be more for smaller payloads, more flexible launch systems, in lower-Earth orbit. And that includes communications as well as remote sensing, as well as microgravity in my opinion. And I think we have begun the process of developing it off-line through the mainstream of the government's programs, but allowing the private sector, through the CCDSs, to develop this in a truly commercial way.

Senator GORE. Well, I am really impressed with what you are doing. And I have learned from Mr. Pawlick and his colleagues how successful it can be. There is really a lot of excitement out there, and you get the best of small business and entrepreneurship and inventors, and the challenging frontier of space. It is close to the essence of the American spirit, and we are really excited about it.

I think you will find a tremendous amount of support on this subcommittee for the proposition that you need steady, reliable funding so you can tell these teams out there competing with each other so ferociously that yes, it is going to be worth your while to take these risks because we are not going to pull the rug out from under you just at the last minute and all 30 of you fall on your faces. At least some of you are going to have a chance to succeed if your proposals are the best.

So we will be fighting for you. And I think, given the size of the total amount, that you should feel somewhat reassured, even in this environment that the chances are good.

Mrs. Lee-Miller, did you want to comment on this interchange? I saw you writing something out. If not, we will move on.

Mrs. LEE-MILLER. Well, the question had to do with whether you can do it cheaper or cut money, going back to Senator Robb's question. And we do not have the grants or the contracts to give to the small ELV companies, but I just want to lend my voice to support to the idea that the more payloads that are developed, the more business will grow.

I think that government, however, will have to resist the temptation to give free flights on other kinds of vehicles that we may have going, because those are potential customers for the small companies, as you indicated. So that is very significant.

In the area of whether individual companies are making their contribution to the growth of this industry, certainly they are contributing to the CCDSs, but I would like to remark that they are also making significant contributions within the general commercial space industry itself.

General Dynamics, for example, has just purchased 60 engines on a long-term plan for launchers that they do not yet have contracts for. But that represents many millions of dollars in private sector investment and their confidence that the marketplace is going to be coming along.

So just as you indicated the need for steady, reliable support, we find that is the case in the policy environment as well. We must have steady, reliable regulatory authority, as well as funding for these programs.

Senator GORE. Now let us talk costs of launch for just a minute. Mr. Rose, is there anything that could be done to stimulate development of a launch system that would come to the range of $1 million a copy?

Mr. ROSE. The one million a copy, we would tend to try to talk in terms of per pound to orbit, because then that takes into account the big payloads as well as the small payloads. I know that there are some companies out there that are looking at the potential of developing other forms of technologies put together that might bring it down to the order of $2,000 to $2,500 a pound. I think right now it is up in the $7,000, $10,000 to $15,000 a pound category for most of the systems.

I think that we have to bring the cost down. Maybe some of it can be done with technology, where you do things, others might be done with the infrastructure that you ultimately set up, and in the size and the complexity of what you do. A lot of costs associated with just integration—if you integrate something into great big payloads, where you have got 20 different people that have to come together, you pay a lot of money for that.

I think we have to start thinking about a commercial way of launching things is somewhat different than we maybe have thought in the past. But we do all have to work in every phase of it to bring that cost down to something in the neighborhood of $1,000 to $2,000 a pound, or I think we will not—you know commercial space will continue—it will not move as fast as it could, let us put it that way.

Senator GORE. Well, let us talk a little bit, Ms. Lee-Miller, about the tension that exists between efforts to stimulate these entrepreneurs and commercial launchers and the government-supported competition overseas. There are so many countries seemingly intent on capturing a monopoly, or at least an oligopoly with the other government-supported launchers on this market that one is tempted to get a little discouraged about whether or not we can realize this dream of a free market in launch services.

We talked a little while ago about the consultations, and we hope eventually negotiations on this, but how do we resolve this if other nations are intent on subsidizing their launches? How do we compete with that?

Mrs. LEE-MILLER. Well, that is a very, very key question that speaks to the very heart of what we are trying to deal with here. Let me give you a couple of responses. The Federal Government is the largest customer for our industry here in the U.S. And to the extent that the Federal Government improves how it operates as a customer, that can be a tremendous asset to our companies.

The Commercial Space Launch Act charged government agencies with supporting and purchasing commercial launch services wherever possible. The National Space Policy reaffirms that. To the extent that our government agencies purchase commercial launch services in a commercial manner, under the regulatory authority of the Commercial Space Launch Act, this will free up our companies to have a predictable business plan that they can project out. They can put in economies of scale. They can make bulk purchases, such as the GD purchase I referred to earlier.

Also, government can play a role in how it focuses research on technology. We spend tremendous amounts of taxpayers' dollars on research in this government. For example, NASA has a component technology program. To the extent that programs already in place can be focused on their applicability to the commercial marketplace, this issue of lowering cost to orbit is an issue that we can address through existing government programs if they are encouraged to work with industry, so that the commercial application of those programs is faster and more direct.

We have had an approach towards space in terms of spinoffs, like if we develop a government program and there happen to be spinoffs for industry, that is good. I am suggesting that perhaps instead of relying on possible spinoffs, that we build in commercial application as a feature of some of our focused research projects.

That is what we see going on in other nations. We see the industry working with the universities, similar to the way Jim is doing in the CCDS, which is exactly the right way to go. We see the governments also providing offset opportunities where competitions that our companies sometimes lose are competitions where they may have come in with a lower price but the government offered sweeteners, as they call it, to the customer.

So we find our industry repeatedly running up against governments. It is a misnomer to assume that our companies are competing with other companies. They are competing with governments. And we have to be very clear about that.

So I think, first, to the extent that the government is a better customer, it must take a look at how we procure launch services, let the companies be the launch service provider, and not trap them into a lot of government oversight and intrusion and involvement in the way they provide that transportation service; and secondly, we must focus our technology; thirdly, we must maintain a consistent and reliable policy environment. The Federal agencies, along with the Congress, must be pretty assertive about insisting that government be willing to change.

A commercial sector is just not going to spring forth on its own. We have to change the way we do business in order to enable it to thrive. So a reliable policy environment becomes a third important feature.

Senator GORE. Very good. I am anxious to get on to the next panel, but I do have further questions for this panel. I will yield at this point to Senator Robb, if you have other questions.

Senator ROBB. No, Mr. Chairman, thank you, I do not.

Senator GORE. Very well. Let me race through the rest of my questions and then we will move on.

Yesterday, the Deputy Secretary of Transportation sent a letter to Admiral Truly regarding the June 14 launch of the Combined Release and Radiation Effect Satellite—CRRES—which will be aboard a General Dynamics Atlas rocket. This letter is part of a growing debate between DOT and NASA about the need to license the launch of NASA payloads by commercial launch firms, and you just referred to a part of this policy, Mrs. Lee-Miller.

Is there a policy agreement between NASA and DOT on how future missions involving government payloads and commercial launched vehicles will be treated? Will all future launches of this kind be certified by DOT?

Mrs. LEE-MILLER. The Congress has authorized the Department of Transportation to license commercial launches under the Commercial Space Launch Act. The General Dynamics launch is a commercial launch, and under that definition it is required of us at DOT to provide regulation of the company.

Let me be clear that we are not licensing NASA, we are licensing the company. For a private company to go onto a launch range and engage in commercial launch activities it must come under the Commercial Space Launch Act, and all commercial launch activities should be regulated under the Act.

Now, it is not DOT's authority to have anything to do with a Government payload. That is the unique responsibility of the Government agency that is sponsoring a particular mission. In the instance of CRRES we have no regulatory authority over the payload—the CRRES mission. However, the launch is being conducted by General Dynamics, and the company is what we are concerned about. So the correspondence that you referred to was informing NASA of the decision that has been made that General Dynamics does fall within the Commercial Space Launch Act and therefore we are responsible for implementing that.

Senator GORE. Do you have a response from Admiral Truly yet?

Mrs. LEE-MILLER. No.

Senator GORE. An informal response?

Mrs. LEE-MILLER. No, not yet. However, let me say that we have engaged in extensive consultations with NASA. Under the act, we are required to consult with agencies regarding licensing actions, which we have done for several months, but at some point in the consultation process the responsible agency has to make a decision. So we have made that decision, but we have not received any response.

Senator GORE. Well, let us know how this works out, because there may be a need for legislation clarifying the jurisdiction over launches carried out on behalf of NASA and other U.S. agencies on commercial launchers. I have no judgment on it. Perhaps others have, but I have not, on the merits of this. But I would like to follow this particular case carefully to see whether or not legislation is needed to clarify the matter.

Mrs. **Lee-Miller**. Mr. Chairman, we certainly welcome your participation and interest in this issue. As I was referring to earlier, the Government has to change the way it does business. We are the biggest customer for these companies, so to the extent that we permit the companies to operate in a commercial manner, we are assisting the growth and development of this industry.

Senator **Gore**. Right.

Mrs. **Lee-Miller**. So that is where we are. Do you have anything you would like to add? [No response.]

Senator **Gore**. Did you have something to add?

Mr. **Musarra**. Well, I just want to emphasize that the licensing action with regard to General Dynamics covers their entire program over the next two years. Some of those launches will indeed be carrying Government cargo. It will be very difficult for us to accord that company a predictable, certain regulatory environment if the requirements that apply to their operations are going to change every time the nature of the customer changes.

In particular, I think we could be led very quickly to some rather absured results in light of the fact that there is at least one company here that is capable of launching two satellites at once. I think that we could imagine a situation where one satellites is a Government one and one is a commercial one. We cannot give them half a license. So I thing there needs to be a rule of reason applied to this, and a recognition that the regulatory environment and the act itself are intended to confer on these companies some significant benefits as well as some regulatory burdens.

Senator **Gore**. Were you itching to make some comment, Mr. Rose?

Mr. **Rose**. Well, other than in the CCDS program, our sounding rockets have all been licensed by the Department of Transportation.

Senator **Gore**. It has worked okay?

Mr. **Rose**. Yes. I have not been a party to this other system. I do not know the Administrator's position, but I guess we will know about it soon.

Senator **Gore**. Very good. I have a lot of other questions, but I am going to submit then in writing. I hope you would be willing to respond in writing.

Senator **Gore**. But before we leave this panel, I want to say again that I am particularly pleased Joe Pawlick could join us. The University of Tennessee Space Institute is doing an outstanding job, and as I said earlier, I am very excited about the work underway there. We could spend a lot more time with you if we had it, but we do not. So thank you all very much for joining us today.

Let me invite our second panel to come forward. We will now have Mr. Mark Oderman, Managing Director of CSP Associates, Inc, of Cambridge, Massachusetts, Mr. David Thompson, President and Chief Executive Officer of Orbital Sciences Corporation in Fairfax, Virginia, Dr. Jack Knox, President of Knox Consulting Company in Napeville, Illinois, and by special request from NASA, Dr. Andrew Wilson, Vice President for Space and Simulation Applications, Maxwell Laboratories, San Diego.

We are going to put your prepared statements in the record in full. We invite you to present a summary, if your would. We are going to start, Mr. Oderman, with you. We welcome you. Please proceed.

STATEMENT OF MARK ODERMAN, MANAGING DIRECTOR, CSP ASSOCIATE, INC.

Mr. ODERMAN. Thank you. Rather than summarize the full contents of my remarks, I think it would be perhaps more worthwile to focus on some of the earlier comments that were brought up in the first panel and those of mine that are relevant to that.

I think when we look at commercial space out over the next 10 to 15 years, it is important to recognize that Government has three roles to play in encouraging and promotion this industry: first is as a funder of R&D, the second is as a consumer of commercial space products, and the third is the regulatory role.

The policies which the past Administrations and Congresses have put in place are addressing all three of these areas, sometimes not consistently. It is important to note that the markets that we are talking about—communications, launch services, remote sensing, on-orbit infrastructure—are all very different markets in terms of the type of risk, the type of technologies which are required, and the proper role which the Government can play.

We look very often to the commercial communications market as the bellwether, or the example for other industries to follow, and in this regard it is important to realize that the communications industry is very different from the launch services business and the remote sensing business.

In the launch services world, I think is it important to note, as has been said already, that U.S. commercial firms do not face a level playing field, and it is therefoe perhaps appropriate to consider whether indeed U.S. policy is consistent with the world marketplace, and especially a marketplace over which the U.S. Government has limited powers.

The second point which can be made is that we must recognize that governments account for 95 percent of the market for space products and services. Therefore, whatever governments do with regard to procurement environment will undoubtedly torque the development cycles and commercial outlook.

Now, in the launch services world, U.S. firms are at an inherent disadvantage in a mixed supply market. The new U.S. policy has U.S. firms responsible for covering both nonrecurring and recurring production costs. This is not the case with Ariane, which is most like ourselves structurally. The Arianespace organization has to cover only the recurring production costs; in the case of the Soviet vehicles and the Chinese vehicles there is really no way of determing that true costs are.

The U.S. policy response in this market, recognizing that supply is greater than demand, has been in effect to try and manage trade: to prevent the export of U.S. technology for rides on nonmarket economy launch vehicles, and to set up rules of the road which is effect will recreate the U.S. policy environment on the worldwide stage.

It is questionable whether in fact that policy will succeed in the long term, and it is also questionable whether in fact restricting the export of U.S. payloads might not in the long run be detrimental to the producers of U.S. satellites. Therefore, we must be thinking in the long term about how to make U.S. firms competitive, and I come back to the issue of research and development. It may be a better strategy for the U.S. in the long term to focus on making U.S. launch services cheaper as opposed to trying to make foreign systems more expensive.

In the remote sensing world, I think we have another case where U.S. policy needs to be revisited. It is clear that in this market we have a situation where we have immature demand and high cost, and an inconsistent policy environment which has left the U.S. system in a continual state of limbo. Once again, the options are fairly clear. I think the industry was privatized much too quickly and we are now trying to find a graceful way to step back into some form of Government support.

Now, the rest of my comments are in the record. I do not think we need to spend a lot of time going through them in detail. I will wait for your questions.

Thank you very much.

[The statement and questions and answers follow:]

STATEMENT OF MARK R. ODERMAN, MANAGING DIRECTOR, CSP ASSOCIATES, INC.

Mr. Chairman and Distinguished Members of the Subcommittee:

I am Mark R. Oderman, Managing Director of CSP Associates, Inc. We greatly appreciate this opportunity to address the subcommittee concerning our views on the status of the commercial space industry, and what efforts the Federal government should be taking to encourage continued expansion in this new area of economic activity.

CSP Associates is a market and management consulting organization based in Cambridge, Massachusetts. Our firm specializes in business planning and market development support for a wide range of aerospace firms, including several firms currently engaged in commercial space activities. CSP Associates has also supported government agencies responsible for the development and implementation of policies and programs intended to spur private sector initiative in space markets.

RATIONALES AND POLICIES

Most of us would agree that a vibrant commercial space economy is a laudable public policy objective. However this agreement masks a variety of public and private sector objectives, and has led to the creation of a hodgepodge of inconsistent policy prescriptions.

The first viewpoint postulates that there exists a broadening number of new investment opportunities in space. The public policy prescriptions which result from this perspective are relatively benign: the proper role of government is to provide moral encouragement, and to avoid swamping firms with red tape, burdensome regulation, or publicly subsidized competition. Government's proactive role should be limited to ensuring equitable rules of trade and fair access to foreign markets.

The second school holds that the private sector would be inherently more efficient than the public sector in the provision of many space goods and services. Today's level of government oversight are often restrictive and suboptimal. Specific examples include government specification of design solutions rather than performance objectives, reliance upon detailed quality control and testing standards rather than product warranties, and duplicative layers of management and technical oversight.

In practical terms two courses of action emerge. First, many have proposed that we revamp the procurement environment, so that the purchase of basic space products and services is functionally similar to the purchase of office supplies - i.e. off the shelf supply or goods and services supplied with product warranties. Second, the government should not be involved in any activity which could be provided by profit-driven companies at lower cost.

The third view is that publicly-funded R&D programs should provide a positive contribution to the American economy (one which exceeds the multiplier that would result from a public sector social services outlay). NASA has always touted its role as an engine of technical progress and innovation, so it is only natural to ask for proof.

In this context commercial space businesses, especially new ventures based on spinoff of government technologies, become an important justification for the public space effort. As a result, policy prescriptions often becomes quite proactive. Appropriate government policies should include favorable investment and tax policies, subsidized use of government facilities, and creative use of the government's purchasing power.

SPECIFIC MARKET OBSERVATIONS

Each commercial space market segment has its unique set of market issues. As a result, a uniform government policy (and more importantly, government action) may not be appropriate, and may in fact be counterproductive.

Communications

As noted above, the communications satellite market is the first, and still the most mature, space market. Applications are well-established and expanding, the technology is relatively mature, and a number of internationally qualified private sector suppliers compete primarily on the basis of price and performance. The primary risk factors for these ventures are those inherent in most markets: the possibility that other technologies might prove more cost effective. The next most serious concern is that a replay of the 1986 grounding of most of the West's launch capability could preclude the ability to launch satellites when needed.

U.S. policy in the space communications field for the past decade has followed the benign pattern. The U.S. government has supported industry through the government's power as a commercial consumer and as a technology development agent in both military comsats and in NASA programs such as TDRSS and ACTS. Most foreign governments have acted in a similar fashion; the recent decision of the Japanese to cancel NASDA participation in the CS-4 program indicates that they too will play by the same basic rules. Governments do not compete in this market against private sector firms, although there is now reason to be concerned about Soviet hardware built by state-run design bureaus.

On the supplier side, the communications satellite business is the one commercial space market where prime contractors have been able to establish separate production regimes for their domestic government (mission driven) and their commercial/foreign (price/performance driven) customers. Because the companies have been successful at separating their government and commercial production lines, U.S. firms have also been free to develop industrial relationships with firms in Europe and Japan. These alliances have led to flexible bidding arrangements, where the prime and subcontractor relationships often flip-flop from customer to customer. These arrangements have been successful for U.S. firms such as Hughes and Ford. In fact, one can compare the success in the international market of these two firms with the relatively low profile of General Electric, which only recently began to actively seek international relationships.

Launch Services

The commercial launch services business is a technically mature industry with significant market fluctuation and uncertainty. This is surprising, given the close symbiosis between the launch services business and the communications satellite industry.

ELV market uncertainties focus on the relationship between global supply and demand, and the differing economic structures of the worldwide suppliers. U.S., European, Chinese, Japanese and Soviet manufacturers are fully capable of managing all phases of launch vehicle development, production and operations. Additional countries, such as India are also developing impressive launch capabilities. However, the total demand for comsat launches is considerably smaller than the anticipated supply of U.S. and European launch capacity; entry of the Chinese, the Soviets and the Japanese will undoubtedly exacerbate this situation.

In a true commercial market, low cost producers would survive at the expense of the inefficient, high cost producers. However, the launch services market is not set up as a level playing field. U.S. providers are henceforth expected to recoup both recurring and nonrecurring investments and earn a return on investment which will satisfy corporate shareholders. For example, General Dynamics has recently made significant investments in the Atlas Centaur launch facilities at Cape Canaveral; these must be amortized in future launch contracts.

In contrast, Arianespace has inherited a fully functional and modern launch family from ESA, but has to cover only its recurring costs of production and operations. The entry of non-market economies is even more problematic, because it is impossible to determine what true costs should be; it is also problematic because Soviet launchers could well be cheaper than U.S. offerings as a result of the much higher flight rates and production economies for some of the Soviet boosters.

U.S. commercial firms are at an inherent disadvantage in this mixed-supply market. Competitor prices often bear little relation to true costs, especially if foreign policy or the value of foreign currency dictate a winning bid irrespective of profit. Moreover, international competitions for domestic satellite system launches typically require bidding not only for the vehicle and launch services, but also offsets, technology transfers and government-sponsored financing. In the case of the recent Brasilsat award to Arianespace, McDonnell Douglas was placed at a considerable disadvantage because of French readiness to provide sensitive engine technology which the U.S. government would not.

In contrast to the comsat industry, the launch vehicle business has never evolved separate products for the commercial and government markets. The launch vehicle manufacturing base remains vertically divided along national lines: U.S. launch systems have very little foreign content, Ariane is a European vehicle, etc. As a result, industrial structure tends to reinforce, rather than diffuse, national competition.

Given that the present market is mercantilist, U.S. actions are increasingly protectionist even though policy advocates free trade. Having launched (no pun intended) commercial firms into the global market, the U.S. government is now obligated to ensure that the playing field is level -- a task easier said than done, as all of the government officials working this issue will admit.

There are two central tenets in the current U.S. government policy. The first is that foreign launch system prices are artificially low, and that in the absence of an acceptable method of determining costs, all players should work to ensure market stability by offering "prevailing market prices" (i.e. U.S. ELV prices). This is an ad hoc situation at best. It both encourages liberal discretion by other suppliers to determine a prevailing market price, and runs counter to the free trade arguments that underlie U.S. trade policy.

The second tenet is that continued expansion of market supply (at least for large launch systems) should be avoided, given the existing disparity between launch supply and demand. As a result, the U.S. government is attempting to manage the market share which new entrants may acquire, and indeed to attempt to discourage new entrants by restricting the launch of U.S. payloads. In the short term, these restrictive policies may have some beneficial effect; however one is led to doubt whether they will ultimately succeed. Once it becomes known that U.S. spacecraft cannot be launched on a particular booster, it becomes more likely that the purchaser may circumvent the U.S. entirely, by buying European, or Japanese, or Soviet spacecraft as well. This approach may also run counter to broader U.S. foreign policy interests.

The first fundamental issue in the commercial launch services business is whether or not the U.S. can cajole, coax, convince or coerce the rest of the world to adopt the same rules of the game. If the answer to this question is yes, then a form of artificial stability can be imposed, and U.S. ELV firms will garner some portion of the market. The next question then becomes whether U.S. firms can compete over the longer term, and develop new and improved products. In this regard, it is appropriate to consider whether these firms can be expected to undertake the large nonrecurring investments to develop new generations of launch vehicles, when governments are performing this function everywhere else.

On the other hand, if the U.S. cannot negotiate a consensus on fair play, then the entire commercial launch services policy will need to be revisited. At this point, the government will have two basic options: (1) to stick to its policy guns, recognizing that ultimately the U.S. firms will be unable to compete in this market; or (2) to adopt similar policies which would allow U.S. industry to offer the same bag of tricks in thinly veiled government-against-government competitions.

Remote Sensing

The development of a U.S. remote sensing industry has been poorly planned, and even more poorly supported, by the Federal government over the past decade. The defining characteristic of this market is a demand which is too small to cover the significant costs associated with the construction and launch of remote sensing spacecraft. Other salient considerations include the presence of subsidized competition (Spot and Soviet systems), and the prospect of at least indirect competition from the U.S. government and others from sensors and spacecraft to be built for the EOS and Mission to Planet Earth programs.

Official U.S. policy in the remote sensing field has been nothing if not embarrassing, and has appeared to ignore completely market realities. Official policy has shifted from abrupt privatization, to a onetime subsidy to support the development of both Landsat 6 and 7, to a onetime subsidy to support only Landsat 6, and now to a reconsideration of whether the whole idea hasn't been a bit ahead of its time.

Study after study has suggested that the EOSAT privatization effort is premature, if the objective is to end all direct government support for the civil remote sensing program. Optimistic assessments project a sufficient market some ten years hence; more pessimistic assessments conclude that while remote sensing has immense value, it is in essence a public good and should be managed as such.

It is clear that EOSAT cannot function as a commercial entity responsible for covering its substantial capital costs. Therefore, given the assumption that maintenance of a civil remote sensing capability in the U.S. market is a priority, it is appropriate to consider whether EOSAT should not be explicitly managed as a public corporation; chartered to operate government-owned hardware (as is Spot Image); or whether the reversion to a publicly owned and operated space segment is appropriate.

On-orbit Infrastructure

On orbit infrastructure is another area where commercial firms are beginning to explore market opportunities. The basic premise is that industry has the technical know-how to manage the design, development, production and operation of these systems.

It is widely recognized that government and government-sponsored missions will account for a majority of the anticipated uses of commercial space infrastructure, at least initially; this is a logical assumption given the overall distribution of space expenditures. Therefore, promotion of commercial on-orbit infrastructure makes sense only if it proves true that the private sector can provide these systems more cheaply than the government can under traditional procurement mechanisms.

To date, the track record for development of commercial space infrastructure has been disappointing. The reasons have been diverse. NASA's attempt to procure commercial platform services foundered on the requirement for termination liability; the Industrial Space Facility was scuttled by its near-total reliance on up front government commitment of several hundred million dollars to help finance the project.

There is some hope that this trend will soon be reversed. Spacehab appears ready to construct pressurized modules to expand the shirtsleeve environment available in the Shuttle. Importantly, the NASA-Spacehab arrangement would cede ultimate design responsibility to Spacehab; NASA's oversight is restricted to ensuring that the module does not pose any threat to the safety or integrity of the Shuttle.

Other proposals are reportedly circulating to resurrect the commercial platform services concept. A significant success in this area could lead to a broadened range of commercial hardware provided for public and private users, presumably at lower costs than would be obtained in traditional government procurements.

Materials Science and Materials Processing

Materials science and materials processing do not qualify for the term "market" at the present time. Technical and market risk are both significant, and there have been no commercially successful programs (although there have been significant technical achievements). The future continues to hold promise, but the sobering experience of McDonnell Douglas' unsuccessful investment in space-based pharmaceutical production has chastened many to both the risks of space programs and the wide margin of technical ingenuity which remains to be played out on the ground.

At present, this embryonic area of endeavor is limited to government and government-subsidized experiments. NASA is investing tens of millions of dollars for the development of microgravity processing equipment and the performance of in-house research. The agency is also attempting to seed industrial commitment through the CCDS program and low cost flight opportunities such as JEAs. Private sector firms are springing up to offer services to those active in this industry, but it is clear that without government funding, there would be few customers for these services.

While few are willing to state it in plain terms, these programs constitute direct government subsidies which are intended to encourage industrial and academic R&D where otherwise it would not occur. The response of many is that these activities are in fact pre-commercial; the major objective of current programs is to compile a basic database of materials properties and processing characteristics in space. It is hoped that sooner or later this research will yield systematic and meaningful insights that can be applied in ground-based materials processing, and perhaps for the production of a limited class of high value products on orbit. Private sector management of these programs, however, ensures that they will develop with an eye on profitable results, and that private sector development and operation of hardware will keep the activities more efficient than a government-managed program.

The scientific community has endorsed space-based research as a valuable and unique are of materials inquiry. Therefore, it is probably appropriate that it receive public research funding. As well, since materials research is a major anticipated use of the Space Station, it would make sense to have an industrial and academic community prepared to take full advantage of these extraordinary facilities.

Similar policies are advocated and implemented by other space powers, hence there is little disagreement as yet on a policy level as to proper public/private roles. Nevertheless, one can see that government support for microgravity businesses may become contentious as the prospect of economic return comes into view. Indeed, we already see political squabbles among the Space Station partners over the terms of access to the laboratories for the Space Station (at least five years before it is launched).

THOUGHTS AND COMMENTS

What this general and superficial review demonstrates that "commercial space" in fact comprises a number of distinctly different areas of activity, each with its own level of technical and market maturity and risk, industrial capability, public-private interdependence and international industrial supply structure.

Hence, it follows that what the U.S. government needs is not a single commercial space policy, but rather a flexible set of guidelines appropriate to the particular technical and market conditions of each area of activity. These policies should recognize the government's ability to facilitate, encourage and actively support different types of private sector activity, based on their overall proximity to commercial market conditions and the international competitive context.

In this regard, it is important to remember that the communications satellite example remains unique. This industry is blessed with a large and preexisting market (communications services), a relatively diversified technical base, and an industrial structure which often lessens the nationalist imperative.

Launch services and on orbit infrastructure represent a middle ground, in which there is definable demand (with the government being a dominant customer) and an industrial base capable of managing all phases of development and operation. Government policy should actively seek to expand private sector management and operation of mature space infrastructure. This will require that NASA and DoD cede day to day management authority and oversight, and rely on contractual guarantees of performance. Industry will respond if commercial rates of return are also permitted. Ultimately, this strategy would not only advance the capabilities of commercial space firms in the U.S., but would allow government agencies to husband precious financial and personnel resources for advanced missions and technology development. On the international front, the current direction of U.S. policy would seem the proper one to pursue in the short term; however, the government should recognize that other, less ideologically pure solutions may be required if the objective is to maintain a viable U.S. ELV industry with customers beyond the U.S. government.

The remote sensing industry will continue to present a more problematic situation: immature market demand, evolving technology and government-subsidized foreign competition will all converge to keep a true commercial U.S. entity a marginal and extremely risky proposition -- one which would not be "bankable" to private sector investors. Government policy should therefore seek to encourage stability in the space segment, while continuing to encourage the proliferation of imagery products.

The extensive and proactive support which is provided to the incipient microgravity materials community is warranted, given the wide range of unknowns. NASA has developed an effective mechanism for encouraging academic and industrial collaboration at this early stage. If pursued with consistency, it will continue to yield positive research results in the next decade.

Senator Pressler's Questions
Hearing on NASA's and DoT's Commercial Space Programs
May 15, 1990

Mr. Mark R. Oderman, Managing Director, CSP Associates, Inc.

1. **How does the risk of commercial (space) activities compare with the risk in more conventional businesses?**

There are two different ways to rephrase this question: (1) how does the risk of commercial (space) activities compare with the risk in more conventional (government space) business; and (2) how does the risk of commercial (space) activities compare with the risk of more conventional (ground-based commercial) business?

Commercial space business differs from government space business in a number of important aspects.

-- In a government space program, competition is limited to the early development phases. Once the contract is awarded, the company is relatively immune from new market entrants. Therefore, the capital which the company puts at risk is limited to those funds expended in the early design and development phases (such as Phase A and Phase B contracts). In contrast, a commercial space firm faces competitive risk throughout its product development and marketing cycle. The size of the financial investment at risk is therefore much higher. As the size of the required capital investment and the perceived competitive risk grows, investments become increasingly difficult to justify unless the perceived rate of return also grows.

-- In government programs, the contractor is often fully funded for termination liability (government's decision to cancel a program), whereas these terms are much less certain for a commercial developer.

-- In a government program, the contractor rarely loses money if there are slips in program schedule (whether caused by launch schedule delays, government-imposed contract changes, or delays in the development or production of the hardware under contract). The costs are usually borne by the government as a cost overrun. Commercial programs are not covered in the same manner; the prospect of significant schedule delays imposes significant monetary costs on invested capital.

-- In a government program, profit is generally negotiated within a range of fees and incentives. These rates of return are typically lower than exist in commercial businesses; the lower fees are probably justified however, by the government's assumption of much of the program financial risk. Commercial space ventures which do not have this buffer for the company involved must command higher rates of return.

-- Finally, because government agencies are usually the largest consumers of commercially-developed space products, these firms are especially sensitive to changes in government budget and policy priorities regarding space. Most companies can make sound business investment decisions in a stable policy or budget environment. In the absence of stability, corporate decisionmakers tend to assign much higher levels of risk to projects which require a particular government policy or orientation to remain in effect for several years. Once again, this drives up the required rates of return, and discourages investment.

Commercial space businesses differ from ground-based commercial businesses in a number of important respects:

-- First, the costs of doing anything in space are significantly more expensive, due to the high cost of space transportation, and the significant design and reliability requirements for spaceflight hardware. Single experiments can cost millions of dollars; for many companies this issue alone makes investments a non-starter.

-- Second, commercial space ventures take a long time to develop. For example, the Spacehab program was initiated in late 1984, it is only now, six years later, that the firm has concluded sufficient capital, negotiated customer contracts, and obtained NASA's concurrence on the overall safety of Spacehab in the Shuttle, that the company is moving forward with production of the Spacehab modules. It will be another couple of years (at the earliest) before the first flight occurs. Hence, it could well be almost a decade before the original investors in the program see revenues.

For areas such as materials science research, the inability to fly experiments quickly and repetitively also discourages top-quality personnel from becoming involved. If an experimenter can only fly once every three to five years, then he must in effect commit his career to a single area of inquiry.

-- Third, as noted above and in my written testimony, government space agencies are the largest consumers of space-related products and services. Hence, the formal policies and guidelines, and the informal attitudes and willingness of the personnel of government space agencies to procure commercially-developed products affects the ability to earn a fair return. If government space purchasers simply treat commercial space products and services as fixed price contracts developed "off budget", then they will certainly kill many commercial space ventures predicated on careful management of schedule, cost and technology.

-- Finally, commercial space business (with the exception of launch services) always face the issue of access risk - i.e. the inability to launch payloads into space such as occurred in 1986. While the U.S. launch system has diversified with the reemergence of U.S. ELVs, we still have only one route to and from space for activities requiring human presence, or for payloads which must be returned to Earth. Another Shuttle accident within the next 5-7 years is a high statistical probability; one can expect another lengthy hiatus in Shuttle flights to follow. Few companies will invest heavily in Shuttle-reliant R&D activities in this environment.

2. **What approaches have commercial space businesses used in attracting capital, and marketing their services? Could the older launch companies be more aggressive in the promotion side of their business?**

Financing strategies for commercial space firms follow directly from how they were created: entrepreneurship and the privatization of government-developed systems.

Entrepreneurial companies propose to development a wide range of products or services at costs which would be significantly less than those developed under traditional government procurement. Small launch vehicles, small spacecraft, Spacehab and ISF have all been examples.

Typically, these firms follow the route of other entrepreneurs. They first invest significant amounts of their personal capital and sweat equity to promote the idea and perform some initial concept definition and marketing. Soon friends and relatives are drawn in. The key stage comes when the new firm must actually begin to build hardware or operate a service - a stage which often requires several million dollars of capital to fund advanced design and then several million more to finance construction. Firms at this point can either turn to the financial markets, or to customers as sources of development and operations funding during startup.

Investment firms have been extremely wary of commercial space investments, for all of the reasons cited above. Because of the high perceived risks of space ventures, they must command significant rates of return (i.e. those commensurate with other investment opportunities, including leveraged buyouts). Few space ventures can offer this promise; hence many go wanting for private sector capital. Interestingly, foreign sources of capital investment have been critical for many firms. Foreign capital sources are often willing to invest for the longer term financial reward and the prospect that the investment may ultimately help develop aerospace capabilities in the home markets.

The second option for firms at this stage of development is to turn to the largest customers for the planned products and services (i.e. NASA and DoD) for some type of advanced purchase commitment. This can work in two ways. First, the government can decide to fund the purchase outright, as DARPA has done with the OSC Pegasus. Cash flow from the government helps to meet up-front development costs. The second option is to conclude a purchase commitment which significantly lowers the perceived market risk, thereby making it possible to obtain commercial financing. This has occurred in the case of Spacehab, where NASA's commitment to utilize the Spacehab module for a limited number of flights (with the prospect that there might be more) was sufficient to convince investors that the firm has a market for its products.

Privatization of government-developed space systems is the second major option for commercial space businesses. Here, the basic issues are that the firm must often take over a large and costly program, hence privatization is usually only open to large firms that can draw on internal resources.

The Landsat situation, however, demonstrates that a policy statement which declares a system to be commercial, and a market which will support it are not necessarily the same thing. Privatized assets are not always developed with commercial purposes in mind, and one should be wary of assuming that any government system could be managed more efficiently under a commercial umbrella.

The marketing approaches of the commercial space firms have been generally adequate and innovative. The basic precept of "go to your customer" has been applied.

Marketing practices to government customers are placed within the marketing practices deemed permissible under the various procurement and ethics integrity standards. The firms meet repeatedly with prospective customers to demonstrate the capabilities of their systems, and to prove to the government program managers that the commercial system offers significant advantages (cost, schedule, performance, or some combination) over existing ways of doing business.

Marketing practices for commercial customers can obviously include a wider range of options. For example, the satellite industry has utilized local production or trade offsets as competitive strategies. U.S. companies are constrained by the Foreign Corrupt Practices legislation (a significant divergence emerges here between U.S. and foreign competitors).

U.S. ELV companies are probably about as aggressive in marketing their launch services as U.S. law and sound financial management will allow. It is interesting to note however, that the significant difference between the U.S. satellite manufacturers and the U.S. launch vehicle companies. The commercial spacecraft manufacturers (Hughes/GM, General Electric, and Ford) are part of larger corporations with significant overseas business activities. Hence their marketing activities can draw on those resources to assist in marketing efforts or in putting together an attractive proposal. Moreover, they have traditionally worked in international teams in which the purchaser can almost always be assured of some local content.

The launch services companies (McDonnell Douglas, General Dynamics and Martin Marietta) are predominantly U.S.-based aerospace defense companies. They have few overseas locations other than local marketing arms, and as a result have little of the corporate resources or leverage typical of the spacecraft firms. Moreover, U.S. launch vehicles have little or no foreign content. As a result, there is little opportunity to offer foreign purchases "a nickel back for every dollar spent".

It is unlikely that the U.S. ELV companies will follow the overseas lead of the spacecraft companies, since they are producers of consumer products. However, it is worthwhile to at least consider whether U.S. policy might not be relaxed to allow U.S. ELV companies to subcontract from foreign sources in U.S. government programs on a limited basis in order to enhance the commercial marketing prospects.

3. Who are the potential customers of space-oriented operations?

At the present time, and for the foreseeable future, the government space agencies are the largest customers of space-oriented operations. NASA and DoD launch the largest number of spacecraft and payloads; ESA and NASDA come in second and third, respectively (not counting the Soviet Union).

Commercial customers of space-operations services in the U.S. are today in early phases of exploratory development (e.g. materials science work being performed under the sponsorship of the NASA CCDS program). Should the activities of these firms prove successful, most will ultimately turn to the commercial sector for payload processing, spacecraft and launch services.

4. Beyond communications satellites and launch services, space commercialization has not been a self-sustaining enterprise. What can be done to diversify and expand the market for space business?

The glib answer to this question is that businesses cannot exist where there is no profit potential to justify investment. Other space business sectors have not evolved because the return is not yet proven. Hence, the real question is what is being done to demonstrate profit potential in other commercial space sectors.

Materials science has matured in the past several years. Original focus was on the manufacture of super products which could not be produced on Earth and which would command fantastic prices. While such products may lie in the future, it is simply too speculative a proposition at the present time for most firms to consider. Nothing short of outright government subsidy of significant portions of the development cost, would change the private sector investment calculation.

The current approach which is embedded in the CCDS program is the correct one. First, there is a need to more fully document the ways in which microgravity can be exploited, and the development of a fundamental research database is required to enable companies to make informed judgements as to the technical feasibility of many projects.

Second, the near term focus of space-based research should turn to the improvement of earth-based materials production processes and products. While not as glamorous as space-produced materials, technical improvements in terrestrial manufacturing could have a significant impact on the competitive position of a wide range of U.S. industries, including chemicals, biological products, ceramics and advanced composites, electronics and metallurgy.

The appropriate government course of action, therefore, should be to fund such programs as NASA's CCDS consistently and adequately (and with appropriate oversight to ensure that funds are achieving their desired results)

Remote sensing is the other field which has failed to "take hold", primarily because few in the transfer process came to grips with the most basic issue: revenues from the sales of spacecraft raw data do not cover the capital costs associated with the construction and launch of the spacecraft. Putting a commercial firm in charge of the marketing of data has accelerated the growth rate of data sales, but it is still far below the breakeven point. SPOT (the French system) implicitly recognizes this in its division of financial responsibility with CNES.

In fact, however, the issue of the size of the raw data market can be considered differently. The U.S. government (Landsat's largest customer) pays for Landsat data in two ways: the purchase of data from EOSAT, and the continuing government subsidy for the development of Landsat spacecraft. The actual cost of the data is therefore much higher than what the purchasing agencies pay for it.

One can therefore ask the question whether it might be preferable for the U.S. government to recognize that the true cost of the data is much higher. Establishment of a government purchasing agency with a budget equivalent to the current government expenditure for both data sales and spacecraft subsidy, combined with a data pricing regime which was based on true costs, would eventually equilibrate the market, and allow the company to pursue data price reductions based on market growth and advancements in spacecraft and data distribution technology.

Three problems would need to be addressed for this approach to succeed. First, as long as SPOT continued to offer data products significantly below cost, then EOSAT data would not be saleable at these higher costs to anyone other than the U.S. government. Hence, it would be necessary to conclude an agreement with CNES and SPOT Image to move towards the same type of full cost recovery pricing basis. There is reason to assume that this is not an unreasonable proposition, since the French government also has to continue large subsidies (which it originally planned to eliminate after the launch of SPOT 2).

The second issue is guaranteeing the continued purchases of U.S. government agencies. Budgets for Landsat data have traditionally been quite small for users such as the

Department of Agriculture and Department of the Interior. They claim that if the cost of the data were to rise without a corresponding increase in their budget to purchase the data, they would simply hold expenditures constant and buy fewer Landsat images. Moreover, it is likely that they would simply shift those funds to other sources of remote sensing imagery, such as aerial photography or ground survey, if the reduced Landsat purchases made it impossible to perform their basic missions. Hence movement to a true cost pricing regime within the government must ensure that the government agencies be allocated enough funds to purchase the same volume of data at much higher costs (i.e. translation of the spacecraft subsidy into higher data purchase prices). For this reason, focusing the entire remote sensing imagery budget into a single organization, responsible for distributing the data to the various government users, would probably be required.

Third, it is possible that the significant data price rise would temporarily disrupt the consumption of data by the private sector. However, it is important to note that few companies actually purchase raw data; what is wanted is the value-added processing of the image that yields economically useful information. According to several sources CSP has consulted, the pricing for the finished products is typically ten times higher than the cost of the raw data. Thus, a significant rise in raw data prices would not precipitate a similar rise in value-added products. Unless the market is extremely inelastic, a 10-20 percent rise in the cost of the product should not result in a permanent decline in revenues. Moreover, the development of a commercial market ultimately assumes that the cost and price of the data must be linked. One can argue that the best approach would be to make the jump in one painful step, rather than prolonging it through a series of gradual price increases.

Indeed, if a permanent decline in data sales did occur, this would be the clearest signal that commercial remote sensing simply isn't an economic enterprise, and government policies intended to encourage it should be cancelled and those funds and effort spent elsewhere.

5. Given the high cost of developing materials in outer space, how can a business make a profit in that kind of venture?

As I noted above, the answers are fairly straightforward: given today's space operations economics, either one produces a product which can command an extremely high price, or one doesn't do business.

Manufacture of high value products in space ("goldmining") has not proven itself, because there is as yet too much technical risk, not enough access to space, and long investment horizons. These basic realities have scared away all but the most intrepid entrepreneurs and investors, and probably with good reason. Production of protein crystals to support biological and genetic research appears promising at the current time, but the jury is still out on whether the demand is sufficient for this to develop into an ongoing business. Pure electronics materials are theoretically possible, but the computer and electronics industry do not yet have any designs which would take advantage of the new materials - a Catch-22.

The use of microgravity for research in ground-based materials does show near-term economic promise because the knowledge derived from the experiment is the high-value, marketable product, rather than the material produced in the experiment. Successful research will encourage more firms to get involved in space-based research, and should eventually resolve many of the questions about the risks and costs associated with space-based manufacturing and the market for space-manufactured materials and products.

Senator GORE. Very good. Thank you. We will have many questions.

Senator Robb, did you want to introduce the next witness?

Senator ROBB. Mr. Chairman, I think the chart on our left and to the audience's right probably introduces the next witness in a very appropriate way.

Senator GORE. Very good.

Congratulations to you, Mr. Thompson and to Bruce Ferguson and Scott Webster, your partners, and to the men and women who helped make your lauch possible.

We are anxious to hear your perspective on the issues we are discussing here today.

Please proceed.

STATEMENT OF DAVID W. THOMPSON, PRESIDENT AND CHIEF EXECUTIVE OFFICER, ORBITAL SCIENCES CORP., FAIRFAX, VA

Mr. THOMPSON. Thank you very much, Mr. Chairman and good morning to you and to the Members of the Subcommittee.

I am Dave Thompson, President and Chief Executive Officer of Orbital Sciences Corporation. Orbital was founded in 1982 and has been one of the fastest growing companies in the United States during the last eight years. We are perhaps best known for two of our commercially-developed space transportation systems, our Transfer Orbit Stage and our Pegasus air-launched space booster.

In these projects and others, government participation in our programs has been essential. I believe that, working together, Orbital and the U.S. Government have, by and large, "done things right" in commercial space and that our mutual success could provide a model for government/industry cooperation in future programs.

Before discussing that, let me provide you with a brief update on Orbital and some of our current programs.

Our company is headquartered in Fairfax, Virginia, and provides lost-cost access to and services in space with a variety of advanced-technology space products. We employ about 650 people and last year we had sales of about $80 million.

Recently, Orbital became the first commercial space company to conduct a public offering of its stock, which was successfully concluded on the 24th of April.

The company's first product, the Transfer Orbit Stage, is designed to boost payloads into higher orbits from both the Space Shuttle and the Titan expendable launch vehicle. We are under contract to produce and deliver the first two TOS vehicles to NASA to launch its Advanced Communications Technology Satellite and its Mars Observer spacecraft in 1992.

In addition to being the first, or "anchor", customer for this new product, NASA has assisted OSC since 1983 in its development and manufacturing.

Our second space launch vehicle, the Pegasus, was successfully launched for the first time on April 5, after it was deployed from a NASA carrier aircraft over the Pacific Ocean. Pegasus uses an innovative, air-launch approach for placing small satellites into orbit at relatively low cost, and is the first all-new, unmanned launch vehicle to be developed in the United States in the past 20 years.

More importantly, perhaps, the Pegasus flight last month marks the first time a privately developed space-launch vehicle has carried a cargo into orbit about the earth.

Like TOS, Pegasus is the product of outstanding teamwork between the U.S. Government and the private sector and could serve as a model for government/business cooperation in the advancement of new space technologies. In this case, NASA, DARPA, and the U.S. Air Force all provided important assistance and support to the Pegasus program.

For example, NASA's Dryden Flight Research Facility provided use of its B-52 carrier aircraft, which was essential to the timely and low-cost development and demonstration of Pegasus. NASA's Ames Research Center provided extremely valuable help to us in computational fluid dynamics modeling, and NASA's Goddard Space Flight Center developed the PEGSAT satellite, which was our primary cargo on board the first launch last month.

For its part, DARPA's early commitment as the anchor tenant for the first and second Pegasus launches was especially crucial. The Air Force also has procured launch services for two upcoming Pegasus missions.

OSC also develops, produces and launches suborbital boosters and sophisticated space payloads. So far this year, we have conducted or participated in four major suborbital launches, all of which have been successful. Later this year we will conduct the first of three scheduled launches of our Prospector suborbital booster in support of NASA's Office of Commercial Programs, as Jim Rose mentioned. We have several other suborbital launches for educational and government customers coming up in the fall.

One of our newest initiatives at OSC is an innovative mobile communications system, which we call ORBCOMM, that proposes to use 20 small satellites in low-Earth orbit to provide worldwide commercial two-way data and position determination services. We have filed with the Federal Communications Commission for permission to construct and operate this system. Possible applications of it include emergency medical and search and rescue communications, environmental monitoring, and real time, two-way personal messaging.

We plan to inaugurate domestic service in 1993, bringing the benefits of space down to earth for millions of consumers in our country.

From this base of experience, I would propose for your consideration the following ideas to promote U.S. leadership in space enterprise in the 1990s and beyond.

First, I think national space policies must elevate space enterprise to a level of parity with civil and defense space sectors.

Second, I think national policy must provide long-term stability and consistency, with provisions for compensation to industry when government policy changes.

Third, early government purchase commitments as an anchor tenant have been crucial and will continue to be so. I cannot overemphasize the government's vital role as the first purchaser for commercial space projects strongly enough. Today, the U.S. Government accounts for over 90 percent of the U.S. space market and about 40 percent of the world market for space products and services. Therefore, its purchasing power is particularly significant.

Fourth, governments should provide technical assistance and should facilitate joint research and development programs as catalysts for industry investment. As an example, the Commonwealth of Virginia's Center for Innovative Technology and Orbital last year initiated a joint program to develop and to use a small, experimental satellite for commercial communications and for environmental monitoring, which has now led to our own, much larger, investment commitment to the entire global ORBCOMM network.

Fifth, export control regulations should be reformed to facilitate international sales and business alliances. For example, restrictions on certain dual use technologies, on the munitions list, should be examined to see if they can be relaxed, and the licensing process should be streamlined, if possible.

Finally, government procurement practices should be changed in four areas. First, procurements should be decentralized, to the extent possible, to shorten delivery schedules and to minimize total costs to the government. Examples are NASA's own CCDS program, which you heard about this morning, and DARPA's Advanced Space Technology Program, which we have also been involved in.

Second, procurements should be based, whenever feasible, on functional requirements, rather than on detailed design and operation specifications, which sometimes increase cost.

Third, procurements should be divided, whenever feasible, into smaller projects that are more commensurate with a corporation's planning horizon and ability to accept financial and other business risk.

Fourth, and finally, procurements should emphasize price competition based on market factors, rather than on the costs incurred by the supplier. The government should only be concerned that it pays the lowest price for a given quality of product or service, and should be less concerned about what the cost of providing that service is. Equally important, profit rates should be inversely proportional to cost, so industries are rewarded for driving costs down, rather than being provided with certain incentives to perhaps keep costs relatively high.

In the last five years, the U.S. launch industry has lost over 50 percent of the market to overseas competitors, and we may now be in danger of losing additional market share in this and other key market sectors. Despite these sobering trends, I believe that the emerging U.S. commercial space industry can produce innovative technologies and low cost products and services that will successfully compete in the international market. I am confident that, with the U.S. Government's support, American industry can guide our Nation to a position of international leadership in commercial space.

Thank you.

[The statement follows:]

STATEMENT OF

DAVID W. THOMPSON
PRESIDENT AND CHIEF EXECUTIVE OFFICER
ORBITAL SCIENCES CORPORATION

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE
COMMITTEE ON COMMERCE, SCIENCES, AND TRANSPORTATION
UNITED STATES SENATE

15 MAY 1990

Mr. Chairman and Members of the Subcommittee:

I am David Thompson, President and Chief Executive Officer of Orbital Sciences Corporation (OSC). OSC was founded by two partners, Bruce Ferguson and Scott Webster, and me in 1982, and has been one of the fastest growing high-technology companies in the United States during the past eight years. OSC is perhaps best known for two of our commercially-developed space launch systems: the Transfer Orbit Stage® orbit transfer vehicle and the Pegasus™ Air-Launched Space Booster, which OSC successfully launched on April 5 of this year with significant involvement from U.S. Government agencies.

Mr. Chairman, I believe a strong U.S. commercial space industry is important for our national technological and economic health as well as our country's place in the world space community. Our Federal Government plays a vital role in fostering the commercial space industry, and reaps the benefits of low-cost, innovative products and services which emerge as a result. Government participation in OSC's Pegasus and TOS programs, among others, has been essential to our success. Together, OSC and the U.S. Government have "done things right", and our mutual success provides a model for Government-industry cooperation. Let me give you an update on OSC's programs.

INTRODUCTION TO ORBITAL SCIENCES CORPORATION

OSC is a commercial space company headquartered in Fairfax, Virginia. OSC provides low-cost access to space with a wide variety of advanced-technology space products. OSC develops and produces space transportation systems, which include space and suborbital launch vehicles and orbit transfer vehicles; space support systems, which include satellite tracking systems and atmospheric environmental monitoring products; and satellite systems and services, which include spacecraft platforms, space instruments and satellite-based data communications services. In the eight years since the company's founding in 1982, OSC has grown from three individuals to a 650-person company with facilities in five states. The company had revenue of approximately $80 million in 1989.

OSC's initial product was a new orbit transfer vehicle known as the Transfer Orbit Stage (TOS), which is designed to launch satellites from the Space Shuttle and the Titan unmanned rocket into higher orbits and planetary trajectories. We are currently producing two TOS vehicles under a contract with the National Aeronautics and Space Administration (NASA), to launch the Advanced Communications Technology Satellite and the Mars Observer spacecraft in 1992. NASA's strong support for this program, particularly at the Marshall Space Flight Center, provided a vital base for the rapid growth of OSC and the hiring of top-flight engineers who have conceived and developed our subsequent programs.

More recently, OSC developed a new low-cost space launch vehicle called Pegasus which pioneers an innovative approach for launching small satellite payloads into orbit. Pegasus recently completed its first orbital launch after deployment from a NASA B-52 carrier aircraft. Pegasus is the first all-new, unmanned launch vehicle to be developed in the United States in 20 years. The successful Pegasus launch marked a number of additional "firsts" for the space industry. Among its technical milestones, Pegasus was the first air-launched vehicle to achieve orbit, the first launch vehicle to use a wing to aerodynamically assist in its flight, and the first winged vehicle to fly at speeds exceeding Mach 8, or eight times the speed of sound. More importantly, the Pegasus flight marks the first time a privately-developed space launch vehicle has carried a payload into orbit. Pegasus was developed in a privately-funded joint venture between OSC and Hercules Aerospace Company during a two and one-half year period beginning in 1987.

OSC's customer for the first Pegasus launch was the Defense Advanced Research Projects Agency (DARPA), in conjunction with their Advanced Space Technology Program. DARPA has contracted for a second Pegasus launch in 1990, while the U.S. Air Force has ordered two launches for later missions. In addition, OSC plans to propose Pegasus in response to NASA's Small Expendable Launch Vehicle procurement. A variety of commercial and international customers have also expressed a strong interest in Pegasus. The Swedish Space Corporation purchased a launch reservation for its Freja scientific satellite, which previously was scheduled for launch on a Chinese Long March vehicle, and OSC has signed a preliminary agreement with the European consortium Arianespace to market Pegasus in Europe.

Pegasus is the product of outstanding teamwork between the U.S. Government and the private sector, and I believe serves as a model for Government-business cooperation in the advancement of new space technologies. OSC identified an emerging market for a low-cost launch vehicle to place small satellites into low-Earth orbit. OSC then initiated the design and development of the launch vehicle (without any prior agreements for purchases), committing substantial corporate resources into securing key partnerships within industry and Government. NASA, DARPA, and the U.S. Air Force all provided a tremendous amount of assistance and support to the Pegasus program. DARPA's role as the first customer for Pegasus launches was especially vital. Its early commitment as an anchor tenant at a critical stage in the Pegasus program allowed OSC to secure the capital needed to complete development of the vehicle.

Several NASA centers supplied technical assistance, use of facilities and key technologies to the Pegasus program. NASA's Dryden Flight Research Facility provided use of the NASA B-52 aircraft, which was essential to the timely and low-cost development of Pegasus. Although commercial aircraft were available, NASA's unmatched experience in aircraft operations from the X-15 program and the availability of the B-52 on a timely basis shortened the Pegasus development schedule and minimized OSC's up-front capital requirements. NASA's Ames Research Center provided extremely valuable expertise in computational fluid dynamics modeling which saved millions of dollars in wind tunnel testing. NASA's Goddard Space Flight Center developed the PEGSAT satellite which was the primary payload on board the first launch.

In addition to Pegasus and TOS, OSC develops, produces and launches suborbital boosters and sophisticated space payloads for scientific, educational and defense missions. So far this year we have conducted or participated in four major successful suborbital launches, with at least six more planned by the end of the year. OSC's High Performance Booster, an improved version of the Aries system, was launched for the Defense Nuclear Agency on January 30; our Minuteman I Consolidated Front End avionics and payload support package was launched by the U.S. Air Force on February 14; and we developed and integrated payloads for the launches of the Bow Shock Ultra-violet Experiment and the EXCEDE III payload for the Department of Defense in April. This fall, OSC's Space Data Division will conduct the first of three scheduled launches of our Prospector rocket for the University of Alabama/Huntsville Consortium for Materials Development in Space, funded by NASA's Office of Commercial Programs.

With TOS, Pegasus and our suborbital vehicles, OSC has added a range of new vehicles to the U.S. commercial launch inventory. We are now working on a ground-launched vehicle called Taurus™, which will be capable of delivering over 3,000 pounds to low-Earth orbit. The first Taurus launch will take place in 1992, again with DARPA as the "anchor tenant" customer.

Our newest initiative at OSC is an innovative mobile communications system that will use 20 satellites in a low-Earth orbit constellation to provide world-wide, two-way data and position determination services. OSC formed a new subsidiary called Orbital Communications Corporation (ORBCOMM), which filed with the Federal Communications Commission on February 28 for permission to construct the system. ORBCOMM proposes to provide low-cost alphanumeric data communications and position determination for emergency assistance, data acquisition, tracking and messaging services using pocket portable mobile subscriber terminals. The ORBCOMM satellite constellation will provide virtually full-time coverage of the world's populated areas and oceans as well as frequent and regular coverage of the polar regions. Possible applications for the system include emergency medical, search and rescue, and roadside communications services; environmental, industrial and remote asset monitoring; property recovery (i.e. automobiles) and animal tracking; and real time two-way personal messaging services. By operating in low-Earth orbit and employing the UHF and VHF radio frequency bands, the cost of subscriber terminals is projected to range from $50 for the simplest, to $400 for the premium, putting these communications capabilities within reach of most Americans. In addition, because the satellites will be constantly circling the globe, service can be provided in foreign countries with only a small incremental investment in earth stations and computer equipment, potentially providing communications capabilities within the reach of millions of people abroad who previously could not afford any telecommunications capability whatsoever. The U.S. trade deficit also would be offset as these American services and subscriber equipment are exported.

ORBCOMM is economically possible as a result of Pegasus' availability to deliver satellites into a variety of inclined orbits at low-cost. We are excited about the international potential ORBCOMM holds, and urge the U.S. Government to place the issue on the agenda for the World Administrative Radio Conference to be held in 1992, so that we may obtain the necessary international approvals to permit full global use of the system. Dependent upon license approval, ORBCOMM plans to inaugurate domestic service in 1993. In summary, at OSC we are building upon our past successes to develop new products and services that will bring the benefits of space down to earth.

RECOMMENDATIONS FOR COMMERCIAL SPACE POLICY REFORM

The Government has been a vital, necessary partner in most of OSC's programs. But it is not sufficient for individual agencies to cooperate on selected projects. Coordinated Government participation in space enterprise is crucial. The U.S. needs to embrace a cooperative attitude toward commercial space, encouraging private-sector initiative through Government incentives. From OSC's base of experience in commercial space over the last decade, I propose the following ideas to this Committee that I believe will promote U.S. leadership in space enterprise in the 1990's and beyond:

(1) National space policies must elevate space enterprise to a level of parity with civil and defense space sectors. National space policy should reflect a recognition of the new way of doing business in space that is now emerging in industry. In the launch vehicle industry, businesses now sell launch services to orbit instead of selling launch vehicles. New programs are being funded with privately-raised capital, increasing both the risk and potential rewards to companies.

(2) National space policy must provide long-term stability and consistency, with equitable provisions for recoupment when policy changes cause damage to the industry. Industry must be able to plan for the future knowing that policies will not change a few years after they are initiated. At the same time, national policy requires "teeth" such that if policies do change, or the Government defaults on its commitments, there is reasonable and equitable compensation to affected businesses. Of course, industry must also be held responsible for failed commitments.

(3) Early Government purchase commitments as an anchor tenant are crucial. I can not overemphasize the Government's vital role as the "anchor tenant" for commercial space projects. One of the greatest strengths of the U.S. Government in serving as a catalyst for space enterprise is its purchasing power. The U.S. Government accounts for over 90% of the U.S. space market and about 40% of the world market for space products and services. It will remain the largest single customer of space products and services for years to come. In addition, commercial customers often look to Government involvement as an implicit seal of approval for a new product, service or company. In both the TOS and Pegasus programs, this commitment was critical.

(4) Changes are required in Government procurement practices for commercial space services and products:

a. Procurements should be decentralized to shorten delivery schedules and to minimize total cost to the Government. With a centralized launch vehicle procurement structure, Government oversight is increased and detailed design and operations specifications are imposed which increase the cost of the launch service. A decentralized procurement approach enables project offices to procure a turn-key service for small to medium programs. The Joust suborbital launch program we are currently participating in, conducted by NASA's Commercial Center for the Development of Space at the University of Alabama/Huntsville, is a shining example of a successful commercially-oriented, streamlined launch vehicle procurement.

b. Procurements should be based on functional requirements, not detailed design and operation specifications which increase cost. Because launch vehicle technology has become increasingly sophisticated and the industry has thirty years of operating experience, Government launch service requirements can be specified at the functional level, such as a certain number of pounds of payload delivered into a certain altitude orbit, rather than at the detailed design and operating level. For example, DARPA's Advanced Space Technology Program specified only the performance requirements for the launch vehicle rather than the design details. This enabled OSC to propose a low-cost, innovative air-launched vehicle that had already completed a substantial portion of its development program.

c. Procurements should be divided into smaller projects that are commensurate with a corporation's planning horizon and ability to accept business risk. Most corporations have planning horizons that are much shorter than the development schedules for large Government space programs. Also, the size of these programs requires a corporation to commit the bulk of its resources to only one project over a period of many years. If space programs can be efficiently broken into smaller pieces with shorter schedules, corporations will have greater opportunity and incentive to attempt to satisfy Government requirements on a commercial basis.

d. Procurements should emphasize price competition that is based on market factors rather than costs incurred by the contractor. In a competitive industry such as the launch service industry, the Government should only be concerned that it pays the lowest price for the service and should not be concerned about what the cost of providing that service is. Profit margins based on cost are most effective when a new technology is being developed for an uncertain or limited market. Launch vehicle technology is relatively mature and the worldwide launch services market is growing. A company that accepts greater business risk by developing an innovative space product or service to satisfy an emerging market should not have its profit margins tied to cost.

(5) Government should provide technical assistance and facilitate joint R&D programs as catalysts for industry investment. Many of OSC's programs would not have been possible without the Government's technical assistance and use of Government facilities, equipment and services. In cooperative R&D programs, Government can generate a large return on its investment in industry. For example, the Commonwealth of Virginia's Center for Innovative Technology (CIT) invested $250,000 in an experimental satellite which

OSC built and will launch on a Pegasus flight. CIT's commitment was instrumental in OSC's decision to invest many times that amount in a new business that has the potential to significantly affect the U.S. balance of trade. OSC will use the satellite as a prototype for its ORBCOMM system. CIT will use the satellite for environmental monitoring and research in Virginia universities.

(5) Export control regulations should be reformed to facilitate international sales and business alliances. The changing international political climate has imposed a new balance in the marketplace between military and economic factors. A revision of the current munitions items list to relax restrictions on certain dual-use technologies is necessary. Industry must be able to respond in a timely and competitive manner to new sales opportunities. OSC is now ready to move into areas where our cost competitiveness gives us an advantage. For instance, Pegasus appeals to countries that lack resources to build their own space infrastructure, but still want to become active in space science. Export control regulations must be structured to permit and encourage the U.S. commercial space industry to capture these new markets.

CONCLUSION

In the last five years, the U.S. launch industry has lost 50% of the market to overseas competitors, and we may now be in danger of losing further market share. Despite this sobering trend, I believe that the emerging U.S. commercial space industry can produce innovative technologies and services that will successfully compete in the international marketplace. I am confident that with the U.S. Government's support, American industry can guide our nation to a position of international leadership in commercial space.

Senator GORE. Thank you very much. We sure appreciate that. We will have questions after the full panel has completed its presentations.

Next is Dr. Jack Knox, President of Knox Consulting Company of Naperville, Illinois.

Welcome.

STATEMENT OF DR. JACK R. KNOX, PRESIDENT, KNOX CONSULTING COMPANY, NAPERVILLE, IL

Dr. KNOX. Thank you, Mr. Chairman.

I think I should emphasize that I am representing AMOCO today, even though I retired last summer.

In your opening comments, you said that one of the goals was to attract industry to space. I agree. We are not going to commercialize space without attracting the manufacturing industry.

I represent one of those industries that does not have the government as a prime customer. We don't have government contracts. We make our profit from selling to other industries that may or may not sell to the government.

We are the sort of industry that does not really care how you launch payloads into space. We are not concerned with communications. What we do need is a microgravity environment in order to prepare products and to do research to help our existing, ground-based products.

You might ask why AMOCO, which is a multi-billion dollar a year company, would get involved in microgravity research. We have lots of products. We sell to other companies. We make a good profit every year.

We got involved when we first heard about the Centers for the Commercial Development of Space in 1985, when the first RFP came out, and the people from Battelle came around and told us what they were planning to do.

We became interested because it looked like for about $25,000 to $30,000 a year cost, AMOCO would be able to benefit from about $1 million a year in research. That is pretty good leveraging.

So, yes, we were interested, even though we figured at the time that we would not ever go commercial on this, but there was a chance to get some really good research.

At one of the first meetings, we suggested to the Battelle Center that one research area in which microgravity might help us was zeolite products. Just a quick statement as to what a zeolite is. It is primarily a hydrous, crystalline silicate that may have had some of its atoms substituted with other materials such as aluminum and sodium. Zeolites are used in your water softeners at home. They are what the industry uses to convert methanol to gasoline. They are used for drying materials, drying gases and drying liquids—that sort of thing. They are also used in laundry detergents.

I should say now that we do not anticipate ever making a zeolite in space that we can justify putting in a laundry detergent. I don't think the price is ever going to come down quite that low.

However, from some of the research that has been done and from some of the projections, we do find that there is a very good possibility that zeolites manufactured in space may well have some commercial value. You can ask, if you are making zeolites now commercially, why in the world would you want to go into space to do it?

One of the problems with making zeolites on earth is the fact that most commercial reactors stir the material. When you stir it, you beat it up, so you get nice, little, fine crystals. And, if you don't stir it, the crystles settle to the bottom. So they don't grow very big.

So normally, what we are talking about is a zeolite crystal that is about a tenth of a mil, one ten-thousandth of an inch. That is not very big. It is all right for a catalyst. But when you start trying to do separations, you would like something a lot bigger.

To give you an example of how zeolites are used in separations, if you take a membrane and put a certain zeolite in it, with one pass you can raise the oxygen content of air to around 30 percent. This is extremely valuable for hospitals, where you want enhanced oxygen content. It is very important in long-range flights, if you want to separate out CO and CO_2 from exhaled air.

If we make zeolites in space, however, and we have microgravity conditions, then these crystals do not settle to the bottom, and we should be able to grow very, very large crystals. If we take these large crystals and we put them in a membrane, then we should have an excellent life support system for flights to Mars, for Moon exploration, or even for long-range bombing flights.

We think that if we can make these highly efficient separation systems, we can probably sell the product, the zeolite product, for somewhere between $10,000 and $100,000 a pound. We are beginning to talk now about a product that we can afford to go to space to make.

By being in access we get an awful lot of research information for our dollars. The research that is done in space should enable us to improve our ground-based operations. The industry as a whole spends anywhere from $20 million to $30 million a year on zeolite research. If we can develop some knowledge that improves our manufacturers capability, we can save an awful lot of money in our ground-based research.

Let me shift gears just a little bit and tell you why we don't do it alone. If it is so great and we have this great potential profitability, why should we join a CCDS and share the results with the other members of the consortium? Why don't we just go to Jim Rose and say we want to fill out a JEA, a Joint Endeavor Agreement, and have all this information for ourselves? Well, if we do that, we have to build our own hardware, for starters.

But we are not interested, really, in learning how to build hardware. We are not interested in learning how to get flights ready. All we want is to do the research.

It can cost roughly $2 million to build a piece of hardware that is certified to fly on the Shuttle.

Industry like AMOCO currently allocates $200,000 a year per man for research in the laboratory. So forget all of the costs of the JEA, forget all of the costs of the insurance for flying and all of the rest of the costs, just building the hardware entails a cost that is equivalent to ten man-years of research in the laboratory. That is for one flight.

If you were the manager of a research department and you had to justify to your president that you spent all this money for one flight hoping that it would give you a commercial product, and ten man-years in the laboratory, ground-based, does not have as good a chance, you are in trouble. If you have to justify it that way, you are going to do the ten man-years on the ground. But, by going through these Centers for the Commercial Development of Space, for the $20,000 to $25,000, we can do enough flights, we can get enough basic information to prove the concept of what we are doing.

Once we prove the concept, then yes, we do have the justification for going ahead on our own, and we will, if the profit is there. We are not talking about the total amount of money involved. AMOCO can afford the total amount of money to do this. But we have to have some justification for profit in order to commit that money, and that is exactly where the Centers for Commercial Development of Space come in. If we did not have them, then we would not be involved in the space business.

So we need their help up until the time that we have proven we have a commercial possibility. We are willing to pay our way, once it gets to that point.

Thank you, sir.

[The statement follows:]

COMMERCIALIZATION OF SPACE FROM A NONAEROSPACE INDUSTRY VIEWPOINT

Presentation by Dr. Jack R. Knox to the Gore Panel
on May 15, 1990

There are several ways in which a nonaerospace industry might like to commercialize space, but they all have the same goal - to make a profit. Today I will restrict my presentation to one area - Materials Processing in Space; one product - Zeolites; and one company - Amoco Chemical Company as an example.

Amoco Chemical first considered the possibility of Space Processing as a new commercial venture in 1985 when Battelle made a presentation of their proposal to NASA to form a Center for the Commercial Development of Space. The leveraging of a small annual cost to Amoco for a large amount of research seemed like a good investment, especially in light of the fact that the programs proposed by Battelle were in line with Amoco's interests. When Battelle was selected to form one of the first Centers, Amoco suggested that Zeolites were materials which might be greatly improved by preparation in space.

Zeolites are inorganic materials which are basically aluminum silicates, usually with another metal substituting part of the structure. They have small (2 - 10 A) diameter pores of a very uniform size and shape. Because of this, they can be used for very efficient molecular filters, and are efficient catalysts when specific metals are substituted for part of their structure. Some of the best known applications are in water softeners, molecular sieves for drying gases, and conversion of methanol to gasoline.

If these materials are known and used commercially, why make them in space?

In a conventional commercial process, the crystals are broken up and damaged by stirring. In a nonstirred process, as the zeolite crystals grow they settle to the bottom and quit growing, with new crystals then forming and then settling. As a result, the sizes of zeolite crystals are generally on the order of 0.0001 to 0.001 inches. By removing the effects of gravity, the crystals do not settle out in a nonstirred process, and it should be possible to grow much, much larger crystals that also have fewer crystal defects.

So why do we need bigger crystals and how much are they worth? Could industry make a profit considering the enormous costs of space research and production?

One of the things that zeolite crystals can be used for is gas purification. It is possible to increase the oxygen level of air from 20% to 30% in one pass through a zeolite filled membrane. It is also possible to remove carbon monoxide and carbon dioxide from air using similar devices. Zeolites are also easily regenerable, so that a device has a very long lifetime. But present efficiencies are very low because the crystals are too small. If high

Then why not just negotiate a Joint Endeavor Agreement with NASA and get on with the work?

You may have noticed that there were a lot of "if", "estimated", and "possible" words in the discussion. There is lots to be done to prove the commercial potential of a space-based process - ground-based experiments, flight experiments, market surveys, and a business plan to mention a few. Current ground-based research in a industry like Amoco Chemical is estimated to cost ca. $200,000 per man-year. To build a piece of space flight certified hardware is at least $2,000,000. Even if there were not additional costs such as ground-based research, insurance, travel, and subsistence costs for NASA reviews, hardware preparations at the Cape before launch, etc., we are talking about 10 man-years of research costs just to pay for the hardware to do the first experiment in space. As research management, what would you figure your odds for a success would be for one or two experiments (flights) vs. 10 man-years of experiments in the laboratory?

With this cost barrier, how can industry ever justify becoming involved in commercialization of space?

That's where the NASA Office of Commercial Programs has really helped us. By our involvement with the Centers for the Commercial Development of Space, we in industry can participate in the research which is necessary to prove a scientific concept. We can get samples made in space which allow us to do end-use evaluation of the product and market acceptance studies. And, we can learn how to interact with NASA in particular and the government in general to jointly develop a U.S. commercial presence in space.

We in industrial research think that there is a potential for profit in the commercialization of space. But, we can't do it independently. We have to have help and cooperation from the government.

Senator GORE. Thank you very much.

Next is Dr. Andrew Wilson, Vice President of Space and Simulation Applications at Maxwell Laboratories in San Diego.

STATEMENT OF DR. ANDREW WILSON, VICE PRESIDENT, SPACE AND SIMULATION TECHNOLOGY, MAXWELL LABORATORIES, INC., SAN DIEGO, CA

Dr. WILSON. Thank you, Senator.

I will describe to you how Maxwell Laboratories, through its participation in the NASA Center for the Commercial Development of Space at Auburn University, in Alabama, came to develop a new commercial product line.

In describing this participation, I would first like to tell you how and why Maxwell became interested in the CCDS program and how it selected and developed a product for development for commercial sales. Then I will discuss the effects of this, not only on our commercial business but also on the space business prospects.

That Maxwell should have come to participate in the program was at the time, 1987, somewhat surprising. After all, the term "space commercialization" did not then and still did not quite make sense to many accountants. There was, frankly, skepticism. Why invest money in research and development, especially with a university, so that commercial space development could occur?

Well, the contrary has, in fact, turned out to be the case. But let's look at the background to all of this.

Back then, 80 percent of Maxwell's business was derived from government-based research and development, primarily in defense. It specializes in development and production of high powered electrical equipment, such as switches, capacitors, and such, and has built one of the largest high powered generators in the world, used for testing of military systems to survivability in nuclear conflicts. Against all of that, only about 20 percent was in commercial sales.

Clearly, there was a need, a need to develop things which were non-government based, which were commercially oriented.

The charter of the Auburn CCDS was to develop space power commercialization. Maxwell's strength was in electrical power and high voltage equipment. The combination made sense, provided that, in the short-term, a market could be found.

A market was identified, and that was that of high voltage power supplies, which were used for powering pulsed lasers, lasers such as are used for precision cutting of metals and etching of other materials—a growing market, a market which was both domestic and foreign.

While a ready terrestrial market was quickly identified, several longer-term space applications were identified. I will return to those shortly.

Having decided that there was near-term terrestrial and longer-term space markets available, Maxwell undertook a program of the design and development of a new product line. This was accomplished with public announcement of the first CCDS generated product in just 13 months. Using a new high frequency transistorized switch technology, a higher efficiency, greater reliability and more compact product was realized.

We had a product with this by this time last year, and since then, production engineering and value engineering have resulted in the first of several models to be announced later this month.

In parallel with this, a more lightweight space version has been built and should be ready for flight by the end of this year.

In retrospect, the CCDS framework provided both the impetus and risk reduction necessary for Maxwell to undertake this bold program. The development would not have occurred without the trigger of this program. Even though Maxwell has invested substantially itself in the product development, it would not have undertaken the project without the risk reduction and collateral benefits derived from the program.

It is an excellent example, I believe, of where public funds primed the process, unleashing the full range of capabilities necessary for the full development to take place, necessary to convert scientific ideas into commercial hardware. It is a case where the benefits of an industry/university partnership were utilized to the fullest extent.

In addition to solid benefits of a new commercial product line, Maxwell derived collateral benefits from its association with a center already involved in space technology. Coming from a non-space based background, it now sees one in the space arena: power systems and components for satellites and for environment sensing data, which would not have been foreseen several years ago.

As I said, the CCDS primed the venture; Maxwell derived a new product; and NASA has a new source for components.

Is the CCDS process valid for a wider range of activities? I believe it is.

The process could be applicable elsewhere in the government—the DOD, for instance—for commercial development of products and services. The CCDS model is a primer for business development in areas where, either on account of risks or lack of incentive, development might not have occurred. The process is necessary to counter balance conservatism in the face of foreign competition, particularly where, as a result of foreign government sponsorship, there is a growing challenge to our industry.

Thank you.

Senator GORE. Thank you very much.

Let me ask some questions first about the commercial launch industry.

Now that we have commercialized the domestic launch industries, we do have to insure that it has an equal opportunity to compete with foreign launch systems. Every effort must be made to provide our own industry with an opportunity to fully establish itself as a viable competitor in the international marketplace, while limiting unfair advantages that foreign launch services may have over U.S. commercial launch companies.

Mr. Oderman, you expressed your doubt about whether this approach can be successful in the long run. If not, what can the Federal Government, as well as U.S. commercial launch companies, do to remain competitive? The challenge is real. The disadvantage we suffer because of foreign subsidies seems real. What can we do?

Mr. ODERMAN. The answer is if we cannot impose our will on the other players in the game, we must either cede the market, in which case U.S. ELV companies will still have their government customers, which are the lion's share of their total market, or we must learn to play in the international game, like the international folks play.

What this would mean for the existing large ELV manufacturers—I exclude my colleague here at the table—is that we must look toward the next generation of systems; we must look toward upgrading the systems we have.

We have cases in point now on two fronts. Number one, General Dynamics, for example, has had to make significant investments in launch infrastructure at Cape Canaveral. That is a situation that none of the other worldwide launch providers have had to face up to yet, and it puts them at a competitive disadvantage. They have to amortize costs. Maybe the U.S. Government should, therefore, restructure those agreements.

More importantly, I think if you look at how Arianespace competes worldwide, they have the ability to pull on their government for collateral technology transfers and trade benefits which U.S. companies cannot do. In fact, in the recent case of the Brazilsat Competition, the McDonnell Douglas team was at a significant disadvantage because U.S. policy with regard to transfer of missile technology was imposed upon McDonnell Douglas, and the French Government did not see a problem with allowing Arianespace to agree to transfer rocket engine technology to the Brazilians.

There is no easy way around it. Given the existing economic structure of the U.S. launch vehicle industry, if other Nations are willing to subsidize those industries, then the answer is we must subsidize as well or lose the market.

Over the longer term, I think we need to revisit the goals of the ALS program. It has been scaled back into a technology development program, whose primary focus is on next generation technologies for the government launched systems, primarily main engine successor technologies for NASA.

Very little of the government funded R&D in propulsion technologies and in launch vehicle technologies has a specific commercial focus, that is, for the development of launch vehicles with the payload categories that commercial customers or international Comsat customers have traditionally used. That is a gap in the technology base, which should probably be addressed.

The ALS program itself should probably be addressed in a more serious way as a new generation of launch vehicle technologies for the country.

The country is going to have to face up as well to the fact that the worldwide demand for launches is not significant. We are talking about events that, in good years, can be counted on your fingers and toes. In bad years, they can be counted on one hand with regard to major launch events.

Small payloads may offer a new market, but for the guys who are out there now, who are competing against Ariane and others, they are competing for large dollar/small number events.

It may be worthwhile for the U.S. to structure itself like Arianespace; that is, to have a single marketing organization that offers a full range of products that has the ability to draw on government launch facilities or cooperation with government to provide financial incentives or trade incentives in cooperation with the sale of the launch service.

Senator **Gore**. Mr. Thompson, you are the newest entrant in this industry. What are your thoughts on the evolution of the international launch marketplace and the role our Federal Government should play in helping the U.S. launch industry?

Mr. **Thompson**. You heard in Mark's answer and in Mrs. Lee-Miller's answer this morning to a related question, a couple of common themes, which I would also echo.

It seems that is nearly universal agreement that Government investment in advanced technology, rather than in specific products or services, is necessary to promote more reliable and less expensive space transportation for U.S. companies in responding to the challenges that we face.

I think that the use of U.S. Government purchasing power is another strong incentive that can be given to industry in this country to make product-specific investments, either in upgrading existing vehicles over the technology level that has been in place now for many, many years with our large launch vehicles, or perhaps moving on to the next generation altogether.

Those two together would appear to form a reasonably good long-term solution to the problem, a solution that might be available by the mid-1990s, if we move rapidly.

The more difficult question is what do we do between now and then. I do not have a complete answer for you.

Issues such as the Australian Spaceport and specific cases of treating the entry of both Soviet and Chinese vehicles into the market are very difficult ones to deal with because of their implications for our satellite industry.

It occurs to me that, perhaps for the first time, the U.S. and the Europeans have very similar incentives to address the problems of nonmarket economies competing in this area. It may well be possible, given our own interests in this country in developing a new generation of ALS or other advanced transportation systems and Arianespace's interest in developing their Ariane V vehicle, that we could get together, at least on a bilateral basis, to establish some "rules of the road."

In doing this, I think we would put our own satellite industry, as well as the European industry, in a position that they could live with while at the same time we would not harm the near-term prospects for our own industries in competing against Soviet and Chinese, and, perhaps in the future, other nonMarket products.

But the short-term is a very difficult problem. I think your recommendation this morning, about trying to achieve, at least with the Europeans and perhaps with the Japanese, a common understanding of the way we are going to deal with that problem over the next five years, is a very good one. It deserves some serious consideration in a thoroughly swift manner.

Senator GORE. Thank you. I feel very strongly about it.

Last week, we had several witnesses who expressed their view that we should have an increased number of small space science missions. I know this panel probably agrees with that. The last panel agreed with it.

But they felt missions costing approximately $1 million—and how you translate that into per pound I guess is a more relevant measure. We heard from an earlier panel about $2,000 per pound. In any event, when we got into launches affordable for universities and other nonprofit research facilities, the question very quickly turned to launch costs and the availability of low cost technologies.

Mr. Thompson, your Pegasus launch vehicle is probably the lowest cost orbital system currently available anywhere in the world. Am I correct about that?

Mr. THOMPSON. I believe that's correct, Senator.

Senator GORE. Can you give us an estimate of what you expect launch costs will be once Pegasus becomes an operational system?

Mr. THOMPSON. It is our plan to try to, by investing in technology improvements and in manufacturing process capabilities, drive the production and launch costs of Pegasus down 15 percent to 20 percent every year for the next five years. We hope that that will allow——

Senator GORE. Is that until you get to free launches?

Mr. THOMPSON. I don't know if it is asymptotic to zero, but certainly to lower levels than we are experiencing now.

We were fairly happy with the cost experience on our first two Pegasus vehicles, which we now have in hand. But we do have room for improvement and will be working very hard to drive the costs down.

Today, I think a $1 million orbital experiment is probably still a little bit beyond the reach of our technology. There are some special cases, however. In the orbital field, I alluded earlier to a joint project that our company and the Center for Innovative Technology in Virginia conducted, which had a total cost to design and develop a new satellite borne by the two organizations of approximately $1 million. If all goes well, that satellite will be launched late this summer or early in the fall, and will demonstrate some useful environmental monitoring, as well as communications applications that could lead later to bigger and bigger things.

But I think that is more the exception than the rule.

In the past, a number of very productive scientific investigations have been carried out on suborbital vehicles, and we see that continuing, not only under Jim Rose's CCDS program, but I hope increasingly back in the mainstream of the science programs at NASA. Certainly, some of the X-ray astronomy missions that have been carried out in the past 20 years have been among the most productive of all scientific investigations conducted by the Federal Government and, at the same time, compared to many others, some of the most economical.

So we think there is an expanding role there which I believe NASA also would agree with us on.

One of the things we are trying to do, in addition to reducing the total cost of the assets that are put in space, is to really drive down the cost of ground equipment that might be used today by universities, perhaps in the future by high schools, and I don't see any reason to stop there. With the advent of personal computers 10 years ago, that is now a fairly common technology at the grammar school level, and it probably is even pushing farther and farther down into our educational system. I think low cost satellite ground stations three to five years from now should be a commonplace occurrence in many of our secondary schools in this country. We would like to try to make that happen.

In addition, we are trying to drive down the cost for industrial and eventually consumer users of using space, such that we can bring space communications within the range of affordability for most Americans. This requires ground equipment that would retail at the level of $50 to perhaps $200. One of the projects we are involved in now is designed to make that level of cost practical for the first time.

So we are working not only on the launch vehicles and the satellites, but putting all of this together to drive down the cost to the ultimate end user of space.

Senator GORE. Once you reach the operational phase and begin reducing your costs 15 percent to 20 percent per year, from what base will you begin reducing them?

Mr. THOMPSON. The cost of our first six Pegasus units, which are in production now, will be in the $5 million to $6 million range per unit. We are going to be driving it down from that base, beginning now, over the next couple of years.

Senator GORE. Is that the launch costs? If you add the cost of the launch to the unit, do you come out to $5 million to $6 million?

Mr. THOMPSON. That factor pretty much would represent the difference between the low end and the high end of the range. The aircraft and range safety costs for a Pegasus launch are of the order of a half million to perhaps a million dollars, depending on launch rates, launch ranges, and other factors.

Senator GORE. Well, it is very impressive. Again, my congratulations on your accomplishment.

You mentioned procurement policies as one of the keys. What specific kinds of procurement difficulties have you encountered thus far in your work with Pegasus, on the Transfer Orbit Stage, and now with your proposed mobile communication system?

Mr. THOMPSON. Well, I think there has been a general recognition over the past couple of years that the government, acting in Mark's second role that he defined earlier as a customer for space products and services, has an enormous influence on the development of the commercial space industry in this country. That role has been of enormous value to our company and I think of value to a great many other commercial space companies today.

One needs only to think of other companies in the mobil communications business and the space infrastructure business to come up with many other examples where this has been extremely helpful.

However, there have been obstacles along the path. Some of those obstacles concern the very long procurement schedules that are characteristic of most Federal agency procurement programs, that typically can take a year to two years to run their course. For a small company, that is a very long time to wait.

In addition, there is often a desire on the part of the government agencies, with the technical capabilities that they have, to help companies in a positive way or to actually cause the redesign of a product so that a common design between government and commercial markets is lost. This drives up the cost to the government. At the same time, it hurts economies of scale in production to the private sector.

Finally, for companies that depend on private capital markets to support some or all of their research and development costs, the current structure of government procurements in space, which is substantially borrowed from Defense Department procurement, can be very detrimental. The incentives that are provided to companies, certainly in cost- plus contracts and even under many types of fixed price contracts, tend to lead companies to not try very hard to reduce cost. In fact, sometimes the incentives work really in the other direction.

At the same time, profit rates are limited to values that are much lower than what companies can obtain in most commercial markets. The net effect is that the government pays a higher price and the private sector receives a lower return on its investment than would otherwise be the case.

There are a number of programs underway now where that pattern has been broken. DARPA's Advanced Space Technology Program is one extremely good example, where the government got a whole series of new launch vehicles and satellites without providing the wrong set of incentives to the private sector to develop products that didn't have commercial applications.

I think more and more of those kinds of programs would help quite a bit as we go forward in changing the ways we do things in government procurement.

Senator GORE. Of course, that was before the White House fired Craig Fields.

I cannot speak for the Subcommittee on this particular matter, but I want to say that my own recommendation during our consideration of the Mission to Planet Earth program this year will be to create an initiative similar to the SBIR initiative, with Mission to Planet Earth to encourage competition among small companies to provide innovative remote sensing initiatives, to get information for Mission to Planet Earth faster and cheaper than is now projected.

A lot of people say that it can't be done and that it's not wise. But I would like to give these smaller companies a chance to show their stuff and to compete, because I have the feeling that some of them will be able to give us remote sensing results faster and cheaper than anybody thinks right now.

Do any of you have any comment on that?

Dr. **Wilson**. I would make some comments here. I believe there have been some significant advances in how detection of changes in the environment, in the chemical constitution of the upper atmosphere, can be carried out much more rapidly, with much higher data rates than had been possible before now.

Certainly we are working with several large corporations. I cannot give you the names, but I believe that not only weather satellites but continuous monitoring of the upper atmosphere will soon become a practical reality.

Mr. **Thompson**. I would certainly support that kind of initiative. I agree that there are some relatively modest-cost and near-term projects that can be carried out that could be a very good supplement to the longer-term Mission to Planet Earth activities underway in NASA and the Global Change Research Program outside of that agency.

So, from my standpoint, we would strongly support that kind of new program.

Senator **Gore**. Very good.

Mr. Oderman, you called the current U.S. policy on satellite and remote sensing "an embarrassment." Given the fact that very few people use the data that the Landsat satellites provide because of the idiotic pricing policy and structure that has been put in place, I would have to agree with you on that score.

Ninety-five percent of all the Landsat images collected have never fired a single neuron in a single human brain because they are stored up in data silos, rotting while people need the data but are unable to get access to it because of the financial and bureaucratic obstacles that have been put in place.

Landsat is not unique in this respect. It is probably the worst single example of this phenomenon. But there are many other examples.

You offered two alternative policies that could be pursued in the future by the Federal Government: first, manage EOSAT as a public corporation, to operate government-owned hardware; or, two, revert to a publicly owned and operated satellite system.

I am not sure those are the only choices. But, among those two, which would you advocate?

Mr. **Oderman**. I think I would clearly advocate the former, which is, in fact, the de facto mode of operation that the French have chosen for the SPOT system, where it was recognized that the current market will not support the capital costs of the spacecraft, but an aggressive marketing organization can at least cover its own operations costs and can, presumably, stimulate the market for users of the data more adequately than can a public sector organization.

That is a model which my firm has suggested in the past to the Department of Commerce and which still bears scrutiny in the current context for evolution of the Landsat system.

Senator GORE. Could agreements like that be entered into without legislation? Or is it your view that we really do need legislation in the remote sensing area to resolve this?

Mr. ODERMAN. The issue, I guess, if I were sitting in EOSAT's shoes is that, without legislation, we have seen broken promises.

Senator GORE. Seen what?

Mr. ODERMAN. Broken promises. The original conditions under which Landsat was transferred to the private sector included a commitment of capital, which was not forthcoming, and for both the operator of the Landsat system and for the users of Landsat data, the uncertainty as to whether, in fact, there would continue to be a data stream and whether there would continue to be an operational U.S. system certainly deterred private sector capital from being invested in any products or services related to that source of data.

Senator GORE. Well, I need to consult with Chairman Hollings and Senator Danforth and others. But it would be my recommendation that we move on such legislation. If anybody has objections to it, I invite them to contact the subcommittee because I think we need to cut this Ghordian Knot. It is just completely out of hand now. We see it interfering with the early design of the Mission to Planet Earth program because we have all this data that nobody uses, that nobody gains access to, and we are designing a lot of very expensive experiments to get the answers to some questions that we may already have the answers to.

It is just that nobody can find the needles in the haystacks to stitch together the answer that is already out there.

This is not a challenge to the program as it is currently designed. I support the new missions. But we need to get the answers to important questions as quickly as possible, and this may be one way to hasten that day.

Dr. Knox and Dr. Wilson, as you noted in your statements, your work is largely the result of NASA's success in developing the various Centers for the Commercial Development of Space. When do you expect the first commercial application of your respective technologies to occur?

Dr. WILSON. Well, we already have realized the first sales of the product developed, and extension and promotion of that market is going forth and to a much great extent this present year.

Senator GORE. Dr. Knox?

Dr. KNOX. I wish I could say the same. However, our first experimental flight to approve concept is currently manifested on USML-1, which is March of 1992. If we assume success on that flight, and that is proof of concept, then the next flight, which is later in 1992, will give us the information we need to make a decision as to whether it is worth commercializing.

The number of flights that we will have to fly, preferably on an ELV, but on the Shuttle or what have you, will probably take another one to two years. This is to prove the scale-up concept, prove that we can make enough, rather than just the one or two grams we will make on the first few flights.

Then we would design a larger piece of equipment that would enable us to work either in the cargo bay of the Shuttle or in an expendable launch vehicle with a separate recovery device.

We are talking about a unit that would make maybe one to five pounds of material per flight, possibly 20 pounds. With the number of flights that we have to do and the current scheduling, the best that we could possibly do would be five years to commercialization. I think seven is probably a much more reasonable estimate.

I would hope profitability would occur shortly thereafter.

Senator **GORE**. If not before

Dr. **KNOX**. That's going to be hard to do.

Senator **GORE**. I understand.

I would like to close by thanking all of you for your willingness to appear here today. I think it has been a very interesting and productive hearing.

I wish all of you the best of luck in the months and years ahead. There is a lot of excitement out there and you all are creating a lot of it. We wish you well.

We will be revisiting these questions discussed here today on a regular basis and doing what we can to play a supportive role in encouraging the development of these exciting ventures.

With that, we will stand adjourned.

Thank you.

[Whereupon, at 12:35, the Subcommittee adjourned, to reconvene upon the call of the Chair.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

STATEMENTS OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

INTRODUCTION

Mr. Chairman, on behalf of the American Institute of Aeronautics & Astronautics (AIAA) I wish to thank you for allowing us to appear before you today to discuss our perspectives on the state of our country's aeronautics activities and particularly the NASA aeronautics program.

The AIAA is a non-profit technical professional society made up of 43,000 engineers, scientists and students in the aerospace field. Our constitutional mandate is to advance the arts, sciences and technology of aeronautics and astronautics and to promote the professionalism of our members. We have 54 technical committees that cover the various disciplines in our field. For the purpose of creating our testimony, the Public Policy Committee established the Institute's Advisory Committee on National Aeronautics composed of members from our technical committees, and who occupy positions of leadership in all segments of the aerospace community (government, industry and academia).

This year our committee spent a considerable amount of time (including a two day meeting) reviewing the NASA Aeronautics Program for 1991 with particular emphasis in assessing its adequacy for meeting our nation's future challenges from the increasing foreign competition. This competition exists in both the military and the civil markets.

THE CRITICAL IMPORTANCE OF AERONAUTICS TO THE U.S.

Since the early eighties the United States has faced an increasingly severe deficit in foreign trade which has reached the $130 billion per year level. The aerospace industry is and has been the number one U.S. trade surplus industry since 1985 when it surpassed agriculture. The 1988 aerospace exports were $26.9 billion of which $20.3 billion were in the civil market - this represented 8.7% of the total dollar value of all U.S. exports. The industry recorded a record trade surplus of approximately $18 billion.

In terms of total sales the aerospace industry booked $114.6* billion in 1988 compared to $110.00 billion in 1987 of which aircraft product sales were approximately $61 billion (despite a significant drop in sales of military aircraft). At the beginning of 1990 back orders for aerospace products were approximately $191.5 billion with $111.3 billion in aircraft, engines and parts. The number of commercial transport aircraft delivered in 1988 increased to 423 compared to 357 the year before, and there were 1273 of these aircraft on order at the beginning of 1989. The $15.9 billion total civil aircraft sales was a yearly record and included an encouraging increase for general aviation aircraft. Also of great importance in this picture is the fact that the aerospace industry employs 1,313,000 workers which represents approximately 6.7% of all U.S. manufacturing manpower.

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* Statistics obtained from the Aerospace Industries Association of America, Inc. - "89/90 Facts and Figures Aerospace"

These statistics leave little doubt of the absolute critical importance of aeronautics to the economic health of the nation. Where would we be without the economic benefits summarized above? However, there is no reason to believe the aerospace industry couldn't suffer the same fate as our ship building industry did after World War II if we don't work to maintain the technology advantage which is the key to superiority of future products, maintenance of the national security and leadership in world sales of aeronautical products.

CIVIL AVIATION AND AERONAUTICAL TECHNOLOGY

The impact of technological advancement on civil aviation since World War II has resulted in millions and possibly billions of dollars saved on direct operating costs. These changes have helped increase the growth of air travel as a method of transportation and kept U.S. industry in a dominant market position.

One of the brightest areas of benefit in the technology advancement field has to do with increased flight efficiency. The NASA propulsion programs which have included the energy-efficient transport, the high-bypass engine, and the hot section technology programs are directly responsible for tremendous gains in product efficiency. There have been reductions of energy consumption per revenue passenger mile by 4.3% per year over the last 15 years and a twofold increase of payload to fuel ratios for current aircraft compared to those of the last generation. The 747-400 aircraft with its winglets, improved airfoil, low drag nacelle, digital engine controls, glass cockpit, and high bypass engine has a thirty percent lower fuel consumption than the original 747-100 aircraft and carries 149 additional passengers. Translated to dollars, this means an estimated $640,000 fuel savings per aircraft per year!

These magnitudes of technological improvement have produced an amazing reduction in airline operating costs - a sevenfold reduction since WW II and an even greater increase in airline travel. As an example of the economic effect, a one percent change in direct operating costs is equivalent to approximately $120,000 savings per plane per year; a one percent change in specific fuel consumption will result in an estimated $17,300 savings per plane per year. It is clear that these gains are directly traceable to NASA R&D expenditures in civil aeronautics, and have placed the U.S. at the leading edge of the world's commercial aircraft market.

Although the demand for commercial aircraft has generally been on the rise over the last forty years there have been significant periods of reduced sales and increased layoffs, for example the agonizing cutbacks in the 1957, 1963, 1971, 1977, and 1983 time periods. The point is that although we are having record high sales at the present, the market is cyclic in nature.

We can without doubt expect to have periods of recession in the future where the worldwide competition will become severe. In the past, our aircraft products have been superior and we have always been able to survive the famines and rise to greater heights.

The situation is changing. The competition from the Europeans and the Japanese aerospace industries is increasing and our technological advantage is being diminished. As a precursor of the future problem for us, the powerful Japanese Ministry of International Trade and Industry (MITI) began a $5 billion, ten-year program to develop the facilities necessary to support supersonic transport development. This will place the Japanese as a strong potential competitor for the introduction of a high speed civil transport (HSCT). In addition, technologies being developed in Europe on projects like the West German Saenger may be applied to an HSCT development. The fact that Airbus has made significant inroads into the commercial aviation market should be cause for our further discomfort.

THE FY 91 NASA AERONAUTICS PROGRAM

For several years NASA has struggled with the problem of stretching very limited research and technology funding across a large number of aeronautical technology disciplines - all of which have large potential payoffs. Compounding the problem is the need to refurbish, modernize and maintain the valuable wind tunnel, simulation, computer and flight test facilities located principally at the Langley, Ames, Lewis and Dryden NASA Centers. These outstanding facilities are supporting a high percentage of the country's overall research and development activities including a significant contribution to defense.

The total NASA aeronautics budget of $935 M for FY 91 is approximately 1.5% of our aircraft sales booked in 1988 and not commensurate with the value of the potential aircraft sales projected for the aircraft industry in the future. The $512 M research and technology aeronautics funding (that must cover the many projects) is less than 3.5% of the total NASA budget. Although there is a modest increase over last year, the need has clearly increased significantly. In all flight regimes that were highlighted in the Office of Science and Technology Policy (OSTP) "Aeronautical Research and Development Goals" report of 1987 we find greatly increased emphasis from the Europeans and the Japanese. There is another phenomena that exacerbates the situation. As the technology becomes more and more sophisticated, the hardware and software become more complex, and the resources needed to make the required advances increase proportionately. This is true in all of the technology disciplines that make up the aeronautical "technology base." A detailed review by our committee of the aeronautics program revealed a number of areas that we would strongly recommend for strengthening should additional resources be made available.

Flight Research - Flight Systems R&T funding of $40.0 M is low when one considers the potential beneficial results of testing the X-29, F-18, F-15, F-16XL and now the SR-71 aircraft. In the past the U.S. has had many experimental aircraft, and as a result, the country built a significant lead in the aeronautics field. During recent years, the country has not actively pursued this practice, and as a result, the technology lead has been significantly diminished. These vehicles frequently serve to bring together evolving technology for the purpose of demonstrating their viability in the environment in which they will be utilized. Therefore, it is believed that a vigorous flight research and technology program is essential to maintaining a strong national defense, as well as providing a favorable effect on the balance of payments. It is recognized that the current X-29 (Forward Swept Wing) and the future X-30 National Aerospace Plane represent a significant continuation of this valuable activity. Analysis and simulation methods are very useful in the development of new manned and unmanned aircraft, however they are highly inadequate for the full design and development task, especially when use of advanced technology results in large uncertainties. The X-29 flight programs have been extremely successful in discovering performance levels that were not predicted by analysis or wind tunnel tests. The formalization of experimental aircraft planning and coordinating is needed in order to maintain a creditable national technology demonstration aircraft program. It is clear that many future aeronautical technology developments will require flight test demonstration because of their interactive, inter-disciplinary nature and the limitations of ground test facilities to properly simulate the environment. Examples of these are hypersonic/transatmospheric flight technologies, advanced super-circulation rotary wing control integration, supersonic VSTOL technologies, unmanned autonomous flight vehicle integration (particularly for high altitude flight), and technology integration for advanced efficient subsonic and supersonic transportation.

Flight research is required for the following reasons:

- To demonstrate the integration of a concept or multiple advanced technologies into a flyable vehicle and to focus technology efforts.
- To fill the gap created by ground test facilities which do not adequately cover the entire flight regime of future operational vehicles.
- To act as a focus for research programs and produce confidence in the advanced technologies.
- To transition and accelerate application of high-risk technologies to full-scale operational systems.
- To reduce acquisition costs and to interface between laboratory research and system application. This also reduces acquisition risks.

- To uplift national spirit and motivation, and display national initiative, technical prowess, and boldness in tackling the unknown.

In summary, there is need for an energetic pursuit of significant experimental and technology verification flight vehicles in order to provide militarily superior aircraft and economic and efficient commercial transportation, thereby retaining the pre-eminence of U.S. aeronautics technology.

Advanced Subsonic and Safety Integration - Subsonic aircraft dominate the world market, exceeding $35 billion total annual sales by U.S. manufacturers alone, and are expected to remain the largest aerospace market well into the next century. The world market in subsonic commercial transports is forecast to be nearly $500 billion between now and 2005. NASA had planned a major thrust, originally at the $60 M level for FY 91, to design and enhance our integrated subsonic technology capabilities. It was to be a multi-year effort characterized to assure continued U.S. leadership in future civil aircraft markets. This project was targeted at the enormous near-future transport market and consisted of subsonic aircraft similar to those now in production and constantly being improved. The target also included a far more vast post-2000 market consisting of some present day type derivatives, but more significantly of both subsonic and high-speed transports which will be based on technology developed and validated between now and the turn of the century. This 1991

NASA program was reduced to $25M and finally cut to zero in order to meet a budget goal. It involved significant safety related projects with aging aircraft efforts leading the way. Airborne windshear sensor exploration, improved damage and failure detection, and high lift devices were among the projects that we feel should be pursued.

Meanwhile, there is the problem of growing demand with an overloaded air transport system infrastructure. World passenger growth has averaged nearly 8 percent per year over the past 15 years. Even at a conservative forecast of 8 percent, passenger traffic will double in 12 years. This growth will be in response to the global economic progress anticipated for the 1990s, led by continued industrial development in Asia. Recent events in Eastern Europe will further increase demand. Needed are increased efforts in commercial air traffic control to find new and improved ways to handle the traffic expeditiously and safely which requires integration of airborne and ground control concepts. Increased research also is required to identify technology problems associated with the aging fleet of commercial transports and to find solutions for those problems.

Also, substantial investment in development of manufacturing technology for large complex systems is needed. There is a significant potential for reducing the system development cycle time, overall efficiency of production with increased quality, reduction of system costs, and major improvements in safety. It has been clearly demonstrated by the Japanese automobile industry that careful attention to design and manufacturing, quality control, and logistics can produce remarkable results in performance and marketplace competitive edge.

HSCT Technology - Worldwide pressure for the development of an economically viable advanced high-speed civil transport (HSCT) over the next few years has grown significantly during 1989. Results of system studies performed under contract for NASA indicate that a 1000 unit HSCT production program would add 400 to 600 billion dollars to the U.S.'s GNP over the life of the program, thus improving the balance of trade between 60 and 175 billion dollars and create between 300,000 and 500,000 + jobs, depending on the U.S. production percent. If the U.S. does not make a vigorous commitment to pursue this objective we could forfeit considerable economic potential and lose our present leading position in the world's civil aviation industry.

An HSCT is a logical product of technological advancement in aeronautical and system-related sciences. The decision to initiate the detailed design and construction of a prototype high-speed civil transport will be based on consideration of the total cost--development, acquisition, and operation of the fleet--as well as of the passenger market and ticket costs.

Environmental considerations are a key factor in the overall design requirements of the aircraft. They will have a large influence on the total program cost and, therefore, on the final decision to proceed with HSCT development. Advancing the technology base will lower the total cost of the fleet, and it is only a matter of time before those costs and the economics of the market reach a "critical mass" and prompt a decision to initiate a prototype design. We emphasize that this decision, while based on technical and analytical judgments, will involve elements of uncertainty and risk as well.

The 1990 NASA high-speed research program oriented toward the critical environmental issues has been increased to $44 M in FY 91. This work is necessary; however, the keys to winning the international competition for an economically viable HSCT are the technology base and the design ingenuity that can be brought to bear. The sonic boom, airport noise and ozone depletion must be addressed, and NASA is correct in conducting research and analysis in these important areas. These issues produce design constraints on the aircraft, but they should be viewed as hurdles to be overcome rather than barriers. Overcoming them, however, will require increased effort and funding support in the aeronautical technologies, and for finding designs to integrate them efficiently. Technology breakthroughs can provide design solutions for reducing the environmental impacts while enhancing the economic viability of the aircraft. The present NASA High-Speed Research Program funding for environmental issues amounts to only a small portion of the commitment needed to provide the basis to compete internationally for this market potential. Therefore, additional efforts are needed to accelerate the aircraft technological design integration areas or we could be studying the environment while we ride a foreign HSCT to Asia. The Committee strongly recommends that this program be established as a National Priority Program.

Rotorcraft Systems R&T - Rotorcraft offer high promise as a congestion reliever. They don't require the long runways of airports so they actually unload the runways of short haul traffic and consequently allow an existing airport to increase its capacity without costly upgrades and repairs. The rotorcraft portion of this country's aerospace activity has probably been its most rapidly growing element in recent years. Capabilities of helicopters have improved measurably and the numbers of aircraft used by both civil and military operators - approximately 40 percent of the military vehicles are rotorcraft - has grown substantially. The trend is continuing as more missions are identified and as lower operating costs bring rotorcraft within reach of more potential users.

NASA needs to strengthen programs in the technical areas of handling qualities (taking advantage of new digital avionics), economical deicing of rotors (for all-weather operations), low air speed systems, improved cockpits for unburdening the pilot, and efforts to predict rotor aerodynamics. The use of composites in Rotorcraft dynamic system components (blades, hubs, control and drive shafts) for improvement of damage tolerance and durability should be evaluated. Also, we believe NASA should play a significant role in the improvement of the tilt-rotor concept performance, the development of other advanced vertical take-off concepts and safety enhancement equipment. We are beginning to recognize their benefits, but we need to continue the research and development effort currently under way in the V-22 program and augment that with NASA research to fully realize rotorcraft potential. This potential is being recognized in Europe and Japan. For example, the French company, Aerospatiale, has studied the civil tilt rotor market and accomplished wind tunnel tests of tilt rotor aircraft and rotors. They have obtained all available results from the NASA/Army SV-15 Program, and are currently leading a European consortium, Eurofar, in design studies and wind tunnel tests of a 30 passenger civil tilt rotor design. This project is in the third year of a three-year study phase and is anticipated to lead to a joint program involving France, Germany, Italy, the United Kingdom, and Spain which will result in civil tilt rotor deliveries before the end of this decade. Wouldn't it be ironic if the United States, who invented and demonstrated the technology, had to buy its rotorcraft from Europe? We feel the $5.1 M is extremely low for this important area of Research and Technology.

Materials and Structures R&T - The FY 91 program funding of $41.4M for materials and structures R&T is low when the potential benefits are considered. There is an immense potential for vehicle performance gains through the use of advanced materials in both primary structures and in engine hot sections. Current technology programs include a large variety of work on a large number of materials such as advanced metallics, ceramics, polymers, carbon-carbon fiber stiffened composites, aluminide matrix-silicon, carbide components, and thermoplastic composites; and in addition, the development of computational structural mechanics methods to analyze and optimize complex aircraft structures. However, there is a need to develop proper fracture mechanics tests for validation and qualification of composites. This must be preceded by research which identifies failure criteria of composites under a variety of loading and environmental conditions. "Damage" needs to be defined and the mechanism of damage formation and accumulation identified. Clearly, the potential benefit dictates the advisability of additional funding of this program area.

Concept and Systems Studies - The identification and assessment of long-term technology requirements can only be accomplished successfully by analytical investigations that explore alternate concepts and define overall sensitivities. Substantial budget increases are recommended for Systems Analysis in the Research and Technology Base budget. This program supports conceptual design studies of a broad range of aerospace vehicles, types and performance to determine technology deficiencies and the sensitivity of vehicle performance to emerging technologies. This information is used in developing research program plans, priorities and resource investment. Most of the systems analysis and conceptual design activity is conducted in-house by NASA engineers and designers. It is important to include the manufacturers as important team members in the process of systems analysis and definition of research needs. These studies should be adequately funded to support design teams in studies with aircraft manufacturers in all performance categories, particularly in business and personal aircraft, commuter aircraft and high performance large transport aircraft. These studies should be undertaken in the context of national and international air transportation system needs. The manufacturers will bring an enlightened perspective to the design and planning process which is sharpened by the realities of manufacturing, quality, performance, and the competitive market. This is an important activity which is inadequately funded. The $10.3 M funding should be increased.

The National Aerospace Plane Program - We applaud the restructuring of the NASP program to aline the schedule with a more realistic technology development. Also, the establishment of a multi-contractor focused national team should help in meeting future competition from nations that have heavy government support.

CONCLUSION

The NASA management has done an excellent job of structuring a FY 91 aeronautical technology program with the resources available. It is our unqualified belief that the NASA aeronautics technology development program is essential to the economic growth and security of the United States in the foreseeable future.

There is a lag in the time required to develop superior products and attain payoffs from those products. A major thrust today may not yield significant dividends until the next century. The transport aircraft market projected between 2000 and 2030 is $1.5 trillion in constant 1988 dollars! If our share of that market is reduced by 2%, due to underfunding of our technology efforts today, a billion dollar per year loss could realistically result. The recognition of a significant increase in foreign competition over the last five years should be a warning to us of a potential economic disaster.

The sale of aerospace products is our brightest performer in world markets today, and aircraft and associated products are the key to continued dominance in the field. Our ship building and color television industries have been smothered by the competition and if we are not vigilant the same could happen to our aeronautical industry.

Aggressive past investments in technology programs have led to superior aircraft systems that are the source of our current position of leadership, and clearly they can pay even greater

INTRODUCTION

The American Institute of Aeronautics and Astronautics (AIAA) thanks you for the opportunity to present our views on the FY91 NASA budget proposal. We believe the administration's proposed budget is superbly designed to meet the diverse needs of a vital and exciting U.S. civil space program, and we urge you to support it as strongly as possible.

The AIAA is a nonprofit professional society dedicated to advancing the art, science, and technology of aeronautics and astronautics and to promoting the professionalism of those engaged in these pursuits. Our membership of over 40,000 professionals is drawn from all levels of American industry, academia, private research organizations, and government as well as from numerous nations abroad.

In 1989 we celebrated two historic events, the 20th anniversary of the Apollo Moon landing and the Voyager 2 encounter with Neptune. Both events symbolize what the United States can achieve through a proper balance of manned and unmanned programs. Apollo taught us what can be accomplished when the nation is committed to achieving a challenging goal. Voyager proved that significant long-term benefits can accrue from relatively modest investments.

The AIAA has always emphasized that a well-balanced and vigorous civil space program is key to advancing science and technology and to improving economic competitiveness. Investments in the civil space program help to maintain our economic, political, and scientific leadership in the modern world. Maintaining pre-eminence is doubly important today, in view of the changes now taking place in the world. Glasnost and the political changes it has wrought make the U.S. civil space program a key element in foreign policy. Moreover, the rapid growth in space capabilities overseas means that if the U.S. does not make the commitment needed for world leadership, others will.

Investments in the civil space program are growing each year, but are still small relative to many other competing federal budget elements. Nevertheless, we recognize that pressures to reduce the deficit will encourage Congress to compromise the pursuit of a vigorous civil space program and therefore trade away long-term paybacks in return for short-term gains. In considering such compromises, we urge, as in past years, that you be guided by three basic principles:

(1) The space technology base is the foundation on which all future space activities and capabilities depend. Support for that base must not be allowed to decay, even though much of its payoff will come in the future.

(2) Completion of current programs, both in science and infrastructure development, should take precedence over the introduction of new programs. Once a program is approved and initiated, it should be completed on schedule and on budget. Program delays and stretchouts always increase costs, and often reduce system capability and debilitate human motivation by degrading the sense of accomplishment. Such consequences must be avoided.

(3) Cutbacks in advanced research, technology, and

development spending must be avoided if they will result in substantially higher development or operations costs later. While lower front-end costs may seem attractive in an austere budget environment, planning objectives must focus on minimizing overall life-cycle costs.

The total cost of a space system, as with any system having great longevity, is often dominated by "ownership" costs rather than acquisition cost. Ownership costs include launch, on-orbit operations and maintenance, and ground logistics and support; acquisition costs include design, development, test, and evaluation and, in some instances, construction and deployment. We cannot allow near-term budget pressures on acquisition cost to impose unnecessarily heavy ownership cost on future generations of users.

OVERVIEW OF SPECIFIC NASA PROGRAMS

SPACE EXPLORATION INITIATIVE

Once again, human exploration of the solar system has been brought to a sharp focus. On July 20th, President Bush challenged us to expand the frontiers of our knowledge by returning to the Moon, this time to stay, and then moving onward to Mars. NASA has accepted the challenge and defined a new program entitled the Space Exploration Initiative (SEI).

It is difficult to justify programs like the SEI in strict cost-accounting terms. We cannot possibly predict the benefits that may accrue from any specific program of exploration and discovery, but history tells us that whenever a new frontier has been opened to mankind by the process of exploration the benefits have been profound -- sociologically, scientifically, economically, and politically. The SEI responds to mankind's basic need to explore, gives us the experience needed to learn how to travel and work in this new realm, stimulates the scientific and engineering curiosity of a generation of students, and opens new opportunities for peaceful international cooperation. Moreover, the SEI is a logical extension of the U.S. civil space program, building on past experience and utilizing much of NASA's existing infrastructure, but also, as directed by the National Space Council, seeking innovative approaches in program management, international cooperation, system architecture, and technology that can reduce the costs and time needed to accomplish the President's goal.

The administration's proposed budget for FY91 begins the process of building a new frontier in space. The first step, called for by President Bush last July, is to complete Space Station Freedom within this decade. Space Station Freedom is an essential element in human space exploration, providing first the scientific and technological information for future missions, and serving later as a transportation node. The second step is to build an outpost on the Moon, to help develop the systems and experience needed to continue on to Mars, and to provide a valuable scientific outpost for studying the solar system and beyond. The last step of the SEI as currently defined is the exploration of Mars, which will first use robot spacecraft to improve our knowledge of the planet and pave the way for subsequent missions that employ human skills and capabilities for detailed exploration and development of a permanent outpost.

To be successful, SEI will require increased efforts in space science and technology and a more complete understanding of how living systems react to the stresses of long-term space flight and the lunar and Martian environments. Before we can establish a lunar base or send humans to Mars we must have a better understanding of the physiological effects of long-duration space flight on the human body. The fundamental design concepts of spacecraft needed for very long manned flights depend on the results of life sciences studies such as those planned for Space Station Freedom. Hence the proposed budgets for these studies, as well as that for the Exploration Technology Program (formerly Pathfinder), must be strongly supported.

Moreover, if this nation is to embark seriously on long-term human exploration efforts, those missions must be developed methodically. Goals and objectives must be established at the outset and pursued in an orderly manner throughout the entire process, making changes only as dictated by the evolution of technology. Careful planning, and a firm long-term commitment to the pursuit of SEI objectives that recognizes the very real budgetary constraints that will exist during the coming decades, will ensure that existing, funded programs are not endangered in the pursuit of this goal.

By far the dominant cost in any scenario of human space exploration is that of launching the necessary mass into low Earth orbit. One of the earliest decisions to be made, therefore, relates to the development of launch systems to reduce the cost of such launches. We discuss this important topic in detail later.

SPACE STATION FREEDOM

Space Station Freedom was cited by President Bush as an essential element in the long-term Space Exploration Initiative. We agree with that assessment. The Station will serve as a testing ground for the development of technologies for human exploration and provide invaluable data on the long-term effects of low gravity on humans. Because it is an unprecedented international effort, Space Station Freedom will do more than demonstrate the peaceful uses of space; it will provide a foundation for undertaking future international elements of the SEI. Freedom will also help restore U.S. leadership in space, provide a source of national pride, inspire our youth, and strengthen our international alliances.

We urge Congress not to cut the proposed station budget. Such cuts in an already tight budget will only compromise the integrity of the program and increase future costs. Congress has already witnessed the effects of its decision to cut last year's (FY90's) budget, which degraded Freedom's originally planned subsystems and damaged our international relationships by deferring the launching of foreign station elements and reducing the services provided to them.

It is especially important to maintain Freedom's present schedule as we begin the critical transition from the preliminary design and review phase into the development, hardware fabrication, and test phase. Further delays in deployment will do more than increase life-cycle costs, which must be paid out of future budgets; they will also delay the benefits that can be obtained from early use, such as the knowledge needed to make critical decisions on the Space Exploration Initiative.

As was so clearly demonstrated last year, such budget cuts also weaken the United States' standing with our international partners. Agreements were signed in September 1988 between the U.S. and Japan, Europe, and Canada. The governments of these partners of ours will contribute nearly $8 billion to Space Station Freedom. Their costs will grow by $200-300 million per year for every year the Station is delayed. We cannot expect these nations to sustain their commitments when we are either unwilling or unable to do the same.

Major budget cuts not only affect international relations in Space Station Freedom; they will jeopardize international cooperation in future projects such as the SEI. Indeed, our allies, dismayed by the abovementioned unilateral U.S. decisions mandated by last year's budget cuts, have already expressed these very concerns in recent hearings. The United States should follow in the footsteps of our allies and authorize the multi-year budget laid out by NASA.

SPACE TRANSPORTATION

Safe, reliable, and timely access to space is essential for a successful U.S. space program. NASA currently has a schedule of nine Shuttle flights per year, increasing to thirteen by 1993. With Freedom scheduled to be deployed beginning in 1995 and the prospective initiation of SEI the demand for Shuttle flights will increase. The current U.S. mixed fleet of Shuttles and expendable launch vehicles (ELVs) must clearly be enhanced.

Despite the many improvements made since the Challenger accident in 1986, there is still a finite probability that an Orbiter will be lost or damaged beyond repair. It is therefore important that the U.S. anticipate such a need and seek alternatives.

The AIAA agrees with the Office of Technology Assessment's (OTA's) recommendation that one or two Orbiters be added to NASA's existing fleet. Additional Orbiters will reduce the serious impact on both Space Station assembly and future exploration missions that would result from loss or damage of one or more Orbiters of the present fleet. It is interesting to note, incidentally, the benefits that accrue from long-term budgetary commitments: the new Orbiter Endeavor, because it was funded in its entirety when the decision was originally made to build it, will be completed on schedule and well under budget.

The Shuttle fleet should also incorporate current technology to enhance system reliability and reduce operations costs. Congress would do well to continue its support of efforts such as development of the Advanced Solid Rocket Motor, technology work on the Liquid Rocket Booster, and improvements on the Space Shuttle Main Engine. In addition, NASA must be able to continue the fabrication and procurement of long-lead structural spares, which will be essential for timely replacement of our operational space capability when the next Orbiter is lost.

The AIAA concurs with the new policy restricting use of the Shuttle to payloads that require human-tended activities, shifting all other payloads to ELVs. In giving Shuttle manifest priority to payloads that require crew assistance, however, it is necessary to implement procurement policies and budgets which enable NASA to purchase commercial ELV launch services without delay, to permit timely launch of those missions currently in the manifest. Congress should approve the substantial increases requested by NASA in FY91 for procurement of these services.

If we are to consider seriously any long-term space exploration goals, however, development of a new, lower-cost, reliable and robust family of launch vehicles is absolutely essential. The Air Force's Advanced Launch System (ALS) concept is precisely the type of system needed for use in the early 21st century and beyond. The AIAA applauds the appearance in NASA's FY91 budget proposal of a strong ALS propulsion research and development effort, but urges a long-term national commitment to the integration of that propulsion work into development of the ALS vehicle family. We use the term "national" because the revised launch requirements of the Department of Defense may not support the high ALS development cost, but the aggregated requirements of both the DOD and NASA, with the SEI in mind, would certainly justify that cost, as was noted recently by Vice President Quayle (in his January speech to the American Astronomical Society) and by the NASA Advisory Council. Indeed, with substantial federal R&D support of an ALS vehicle family (perhaps renamed "America's Launch System"), our nascent commercial launch industry, by building and marketing the launch services of such a vehicle family after it has been developed by the government, would find itself able to compete for next-generation large payloads against the European-government-supported Ariane 5 and perhaps even Soviet launchers.

The goal of the ALS concept is to deliver payloads ranging from 33,000 to over 450,000 pounds to low (220 n.mi.) Earth orbit, compared to the Shuttle's lift capacity of about 50,000 pounds, with a cost objective (for the optimum vehicle configuration) of $300 to $500 per pound. Congress should strongly support the proposed FY91 NASA budget for propulsion-related technology, which is the key development requirement for the ALS vehicle system.

Interim needs for heavy-lift capability might be met by Shuttle-C, an unmanned cargo vehicle that utilizes components already available from the Shuttle program. Although not nearly as cost-effective or reliable as ALS concepts, Shuttle-C has been cited as a prospect to offload the heavy Shuttle space-station deployment manifest by carrying the heaviest payloads and most of the logistic payloads for the station in the 1990s (thereby both reducing the probability of a Shuttle loss during station deployment and offering backup capability should one occur), as well as a key element in the early phases of establishing a lunar outpost. Shuttle-C could also serve as a flight-test vehicle for both the ASRM and the LRB, and particularly for the new 580,000-lb-thrust Space Transportation Main Engine now being designed as a low-cost, highly reliable engine for multiple use in ALS core and booster configurations. Although the operations cost of Shuttle-C will probably remain too high for frequent use, its development as a Shuttle backup for space-station deployment, as well as for occasional payloads requiring heavy-lift capability until the ALS becomes operational, would seem warranted. Despite its as-yet undefined role in the SEI, therefore, a new start for Shuttle-C development should be considered seriously at this time.

Before making a commitment to Shuttle-C development, however, care must be taken to (a) define its prospective missions, (b) establish a space-station plan for its use that includes recovery from failure of a Shuttle-C carrying considerably more payload than a Shuttle, and (c) define a policy that precludes government operation of the vehicle in competition with the private commercial launch industry.

It is also necessary to look beyond the Shuttle and even ALS technologies toward future cost-effective, reliable space transportation systems. Hence the AIAA applauds the strong budgetary support proposed by the administration for the joint NASA/DOD hypersonic National Aerospace Plane.

Other transportation elements in the FY91 budget, both of which are essential to safe, cost-effective use of Freedom and to subsequent human-exploration missions, are the orbital maneuvering vehicle (OMV) and an assured crew return vehicle (ACRV) or, alternatively, a two-way personnel launch system (PLS) dedicated to carrying human crews to and from Freedom or other orbiting platforms.

SPACE SCIENCE

The current emphasis on the Space Exploration Initiative must work in harmony with and not be allowed to overshadow the importance of space science missions using robot spacecraft. Such missions were the foundation of the U.S. civil space program, serving to demonstrate the technologies needed for human space flight as well as providing unprecedented knowledge about the Earth, the planets, and the Universe.

The Voyager 2 flight cited above is a prime example of the value space science programs bring in the search for better understanding and increased knowledge of the universe we live in. Voyager's mission, which extended far beyond what was originally projected, illustrates the long-term benefits that can be achieved with a small initial investment and a strong commitment by both the government and the people involved in the program. Another example of a small investment which, although not in the proposed FY91 budget, could be of major significance to the global well-being is expansion of studies aimed at detecting and tracking Earth-approaching asteroids. We attach to this statement a recent AIAA position paper on this subject.

The proposed FY91 budget includes two space science elements essential to the support of any future exploration initiatives: the Mars Observer and the Lunar Observer. The Mars Observer program will augment the data collected during earlier Mariner and Viking missions by mapping the surface composition, atmospheric structure and circulation, topography, gravity, and magnetic field of the planet Mars. This information will help guide decisions on future human flights. The Lunar Observer program will provide similar data on the Moon's topography and surface composition, information that is needed to identify the best locations for future lunar outposts.

Besides providing valuable information for human space missions, robot spacecraft planned for the 1990s will help scientists unlock the many mysteries of our universe. Two of the "Great Observatories," the Hubble Space Telescope and the Gamma Ray Observatory, are scheduled for launch later this year. Both these programs will afford scientists opportunities to perform experiments that could never be conducted on Earth due to the distorting effects of our atmosphere. A third "Great Observatory," the Advanced X-Ray Astrophysics Facility (AXAF), will study stellar structures and their evolution, active galaxies, and clusters of galaxies. Timely development of the AXAF is crucial in order that it be flown in concert with the Hubble Telescope and the Gamma Ray Observatory, thereby enhancing the scientific return of data and providing a complete picture of our universe.

The AIAA endorses a long-term program of space science missions of the type proposed by the National Academy of Sciences' Space Studies Board and adopted by NASA's Office of Space Science and Applications. Such long-term programs cannot be carried out effectively, however, when their budgets are subject to annual change. Multiyear commitments for space science programs are needed to provide the fiscal stability commensurate with projects measured in decades rather than years. In that context we applaud the Committee's decision last year to reinstate funds for the Gravity Probe B program, and again urge you to consider multi-year budgetary commitments for the Space Studies Board's excellent program. However, although the

Committee's support of last year's new start on the Comet Rendezvous Asteroid Flyby (CRAF)-Cassini mission was commendable, and the placing by Congress of a budget cap on that project may have made good sense in that particular case, the general practice of placing fixed budget caps on long-term technology-intensive programs is antithetical to the rationale of multi-year funding for such programs.

COMMERCIAL PROGRAMS

Commercial space activities involve industry, government, and academia in a common effort to generate net benefits through the commercial development of space. Opportunities for initiating or continuing commercial space development exist in at least six areas: satellite communications, Earth observations, space processing and research applicable to ground-based manufacturing, life science, transportation, and ground and orbital services.

As commercial enterprises increase their participation in U.S. space activities, NASA must play an active role in encouraging and supporting private-sector investments by expanding the agency's traditional practices of funding research, technology advancement, and demonstration of new technology areas having commercial promise, and of helping develop commercial markets by purchasing needed goods and services whenever possible.

In this context, the AIAA supports NASA's creation and support of Centers for the Commercial Development of Space (CCDSs) to conduct research aimed at the identification of potential commercial projects. These consortia of government, universities and industry have proved to be one of the better mechanisms ever established to encourage investment of private capital in commercial space development. The program has grown to include 183 companies and 48 universities, and has already identified more than 60 specific experimental payloads that have the potential of becoming marketable products. It is important that the role of the private sector in these CCDSs relative to that of government continue to grow, and therefore the federal level of budgetary support should be related to private-sector participation. NASA should therefore define specific qualitative and quantitative goals to help establish that level of support.

Many of the experiments identified by the CCDSs are dependent on the availability of highly limited Shuttle facilities. The AIAA has taken the position that the shortage of microgravity flight facilities is the single most critical factor limiting research in microgravity processing, so we are delighted to see that the proposed FY91 budget recognizes this urgent need by providing substantial support for suborbital commercial launches and encouraging the leasing of orbital facilities for CCDS flight experiments. Early deployment of Space Station Freedom will provide an ideal environment for experiments requiring human presence, and will also help alleviate the overload on the Shuttle's manifest. The AIAA also supports the development and operation of other orbital facilities for commercially oriented materials, materials processing, and life science research. Such alternatives will be especially important as SEI-related activity on the Station increases and refined materials-processing test requirements call for lower levels of microgravity.

Although space will be commercialized by the private sector and not by the government, industry should not be expected to undertake the full investment alone. It is imperative that NASA maintain a vigorous role and provide sound commitments to commercial space development projects. The initial investment is likely to be returned many times over by the growth of new, prosperous industries marketing new products and services. Hence the AIAA strongly supports the substantial increase for these activities in the proposed FY91 budget, and urges Congress not to pinch pennies in this critical area. We cannot expect to motivate industry investment in R&D for commercial space programs when the supporting government programs fall victim so often to arbitrary and unexpected budget fluctuations.

SPACE TECHNOLOGY ADVANCEMENT

As stated earlier, technology is fundamental to all space activities. NASA currently has two focused programs underway to develop the hardware, software, design techniques, and data needed for future missions. The Civil Space Technology Initiative (CSTI) is developing technologies for efficient and reliable access to space, and the Exploration Technology Program (formerly Pathfinder) advances critical technologies in the areas of manned and robotic missions to expand human presence into space.

Both these programs represent NASA's effort to replenish the technology "bank" we have been depleting for the past two decades. There is no hope for pursuing major space exploration goals without firm, consistent commitments to these technology efforts. We deplore the cuts made in the past two years' Exploration Technology Program budgets, and urge you to support both CSTI and Exploration Technology this year, along with other cutting-edge technology advancements such as those needed for ALS, for Freedom's laboratory facilities, and for materials processing.

We are particularly concerned about support for the key technology programs in the Exploration Technology budget that are aimed at reducing the development risk for future exploration initiatives. These include advanced life support, power, propulsion, and aerobraking. Where multiple technology options exist, parallel technology advancement programs should be undertaken until a clear choice is indicated.

The proposed Life Sciences program is strong in its objective of understanding the relative benefits of artificial gravity vs. the development of countermeasures, and in its life-support technology goals. However, the psychological issues associated with prolonged exposure in a confined space are not given adequate attention in the FY91 budget proposal, nor are cooperative efforts with other agencies having experience in this area; e.g., the Navy's submarine crew studies and the National Science Foundation's Antarctic experience.

MISSION TO PLANET EARTH

As the nation considers the prospects for exploring space more intensively, it is important that we also continue to expand our knowledge of our own planet. We are becoming increasingly aware of the delicate relationship between human civilization and the global environment. The effects of deforestation, burning of fossil fuels, and widespread use of certain industrial chemicals on depleting the ozone layer, creating unacceptable air pollution and acid rain, and raising the threat of global warming have been given considerable press.

"Mission to Planet Earth" is a vital program that will enable the global community to better understand how people affect the environment. The program will gather data on the Earth's climate and weather, its atmosphere and clouds, its land, its crops, its forests, and its ocean temperature and currents. The information gathered will enable the leaders of our world to make intelligent policy decisions to protect the future of the planet and of our children.

The Earth Observing System (EOS) is the centerpiece of Mission to Planet Earth. EOS will consist of four polar-orbiting platforms, two to be provided by the U.S. and one each by Europe and Japan. These platforms will contain instruments designed to observe the Earth's land areas, atmosphere, and oceans for 15 years and thereby provide scientists with the data needed to develop comprehensive models for the accurate prediction of global change. The first of these platforms, EOS-A, will focus on land mass observations; the second, EOS-B, will concentrate on the oceans and the atmosphere. Congress should support the resources requested in the proposed FY91 budget to initiate development of EOS-A and to continue technology advancement for

EOS-B.

Because EOS will not become available until late in the decade, the urgent need for early data to assist in formulating climate-change models will be met by instruments currently funded through the Earth Probes program. Also, the Upper Atmosphere Research Satellite, the TOPEX/Poseidon satellite, and the radar scatterometer will address highly specific problems in the Earth environment such as ozone depletion. Programs that fly in concert, such as EOS and Earth Probes, enhance the scientific return of data and ensure a sound base of knowledge. The FY91 budget proposed for these activities should be supported as strongly as possible.

EDUCATION

The Space Exploration Initiative and the Mission to Planet Earth constitute a challenge our nation today and in the years to come. The very nature of these programs requires a long-term, sustained commitment by those who inspired and initiated them and those who will follow in their footsteps. Because NASA will experience a high percentage of retirements within the next few years, the agency must begin as soon as possible to rebuild the workforce needed to carry the civil space program into the 21st century.

But simply rebuilding its current workforce isn't enough. NASA must prepare for the next century when programs like MPE and SEI come to fruition, and begin preparing to meet the personnel needs they will engender. The people who will become our future scientists, engineers and mathematicians are currently in elementary school. It is imperative that the nation plant the seeds of inspiration today in order to ensure the technically literate workforce needed to function in the high-technology world of tomorrow.

This will not be an easy task. Current studies of student capabilities show that the U.S. ranks low in the areas of math and sciences compared to other technically advanced countries. In addition, the United States graduates a smaller percentage of engineers (8% of total graduates) than Japan (20% of total) or the USSR (39% of total). Moreover, other countries are increasing the fraction of their labor force employed in science and engineering more rapidly than the U.S.

It is quite clear that the U.S. is threatened with becoming a technologically illiterate nation in an increasingly technologically dependent world. Programs like NASA's Designated Space Grant Colleges/Consortia and the federal Head Start Program will help to ensure that our nation's most vital resource, human capital, is not eroded.

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We thank you for this opportunity to present our views on the FY91 NASA budget proposal, and will be pleased to respond expeditiously to any questions you may have.

STATEMENT OF RALPH E. CRAFTS, PRESIDENT, ADA SOFTWARE ALLIANCE

Introduction

Mr. Chairman and Members of the Subcommittee, thank you for giving the Ada Software Alliance (ASA) the opportunity to submit testimony on the budget for the National Aeronautics and Space Administration (NASA). ASA was formed in 1989 to promote and enhance the use of the Ada programming language and associated software engineering technology in any and all applications and programs where the use of Ada can benefit the customer.

The current version of the NASA Fiscal Year 1991 budget, although detailed in most areas of NASA operations, appears to overlook a critical ingredient in the successful pursuit of the agency's space programs--software. To properly address and overcome the tremendous challenges posed by space system software requirements, NASA decided several years ago to standardize on, and mandate the use of, a standard computer programming language: Ada. That is why we believe it is important for NASA and this Committee to focus on the software issue.

The Importance of Software at NASA

The development, purchase, and maintenance of software for NASA consumes more than 20 percent of the total NASA budget. NASA and its contractors develop between 15 and 20 million lines of code each year, at an annual cost of about $1 billion. The annual cost of writing new software exceeds 10 percent of the total NASA budget. The cost of routine maintenance, along with the purchase of commercial-off-the-shelf software, and the building of special-purpose software, exceeds an additional 10 percent of the total NASA budget.

As an example of how critical and costly software is in NASA projects, the software required to support the first shuttle launch exceeded 20 million lines of code and cost more than $1.2 billion. The annual recurring cost for shuttle flight software alone is more than $30 million. Figure 1 shows the various software components required for the shuttle.

NASA usually contracts for more than 90 percent of its software development, and does the remainder internally. The role of software at NASA has changed dramatically over the years, as the complexity of the manned spaceflight programs has increased. As shown in Figure 2, the growth in demand for software at NASA is expected to continue, and the rate of growth will also increase. An internal NASA report notes, "NASA will be unable to supply the number of software engineers required to meet this increased demand."

The Potential of Ada at NASA

According to a NASA working group report, "Ada has promise for more efficient production of higher quality software through its support for the principles and goals of software engineering. The discipline of software engineering has the potential to alleviate the pervasive problems that constitute the "software crisis." The report goes on to caution that "Ada is not an end in itself but rather a means to achieve the goals of software engineering."

The working group also recognized that the "Ada transition" would not be trivial:

> "To realize the promises of Ada, an organization must be willing to make changes to incorporate both Ada technologies and software engineering principles into its software development process. Changes to the training program, software tool suite, and software standards and practices are necessary parts of the adoption process."

NASA's Ada Five-Year Plan

In March of 1988, the NASA Information Resources Management (IRM) Council expressed their concern that NASA lacked the infrastructure necessary to support the use of Ada for major NASA software projects. The Council also observed that NASA did not have a coordinated strategy for applying its experiences with Ada to follow-on programs. The Council appointed an inter-center Ada and Software Management Assessment Working Group (ASMAWG) to investigate Ada's status at NASA and make recommendations to the Council.

One year later, the ASMAWG submitted their report, entitled, "Ada and Software Management in NASA: Findings and Recommendations." Based on that report, as well as the "NASA--Evolving to Ada: Five-Year Plan" (dated April, 1989), and an internal report on the response from industry and NASA from a NASA symposium/forum in June, 1989, ASMAWG offered the following conclusions:

--Ada is an appropriate vehicle to support the evolution to improved software practices in NASA.

--Although NASA offers courses in Ada and software engineering, the training programs are not adequate to accomplish a transition to Ada.

--NASA has very little experience with Ada, and current plans do not provide for building an experience base adequate to meet existing commitments for the use of Ada.

--NASA Ada projects have often selected or developed sophisticated tools and methods; but software reuse is still in a rudimentary state.

--NASA software management has been weak in two areas pertinent to this report:

1. agency-level planning for the use of state-of-the-art software engineering practices;

2. project-level management of software risks, including those associated with Ada.

--NASA does not have an adequate set of agency-level standards and internal organizations to provide direction in software engineering and to support the evolution to new software technologies such as Ada.

--Although NASA has sponsored extensive research in software engineering, some of which has dealt with Ada-related technology, the agency has not had a broad, coordinated program of research, experimentation, and pilot projects.

--NASA does not have an adequate program of collection and use of metric data about the software development process.

The ASMAWG went on to make the following recommendations:

--NASA should adopt Ada as its standard programming language.

--NASA should establish a Software Engineering and Ada Implementation Task Force.

--NASA should develop and adopt tailorable standards for software development, management, and assurance.

--NASA should evolve toward a common software support environment.

--Each NASA center should develop a plan for evolving to Ada.

--The Task Force should ensure the development and implementation of an agency-wide core curriculum in software engineering and Ada. Each NASA center should adapt the core curriculum to its specific needs.

--For any "critical" project, management should be required to develop and implement a written risk management plan.

--NASA should establish an Ada incentive program for its software contractors.

--The Office of Aeronautics and Space Technology should plan and coordinate agency-wide software research and development, more of which should support Ada.

--NASA should establish an agency-wide program to collect and use software metrics.

--NASA should establish a Software Process Engineering Task Force to support the evaluation and improvement of the agency's software acquisition and in-house development processes.

ASA finds these to be laudatory recommendations. What we are concerned about is the implementation of them.

NASA's Ada Transition Model

The ASMAWG's Ada Transition Model emphasizes the importance of software engineering: "It would be more effective to adopt sound software engineering principles without Ada than to adopt Ada without sound software engineering principles." The value of Ada is as a vehicle for the implementation and use of sound software engineering.

To effect the use of Ada as a software engineering vehicle, a knowledge base must be established within the organization; this means a significant commitment of resources for training. As shown in Figures 3, 4, and 5, deriving reuse, productivity, and error rate benefits from the use of Ada is a function of experience. Generally, the benefits start to accrue on the third Ada project.

Multi-year Transition Plan

A three-phased Ada transition plan was proposed by the ASMAWG, as depicted in Figure 6. The plan calls for NASA to be "100 percent Ada" by 1997.

According to an internal NASA report, "Industry was surprisingly positive about the proposal to mandate Ada and adhere to agency wide standards." There was also a "large consensus" against training incentives, and against the development and mandate of a common software support environment (referring to the NASA SSE--Software Support Environment project).

The various NASA centers remain somewhat divided on the Ada plan and mandate. Of the nine centers represented, four of them are strongly in favor of the plan, three are against it, and two "are in between." Those opposed to the plan appear "surprisingly ignorant" in the field of software engineering, are not aware of the software crisis, and offer no alternatives to the Ada transition plan, according to NASA's own internal report.

Most NASA vendors feel that the phased transition plan is too long--they would rather accomplish the transition in a shorter period of time. The other consensus is the opposition to the SSE--contractors would rather use their own support environments.

Of the NASA centers opposed to the use of Ada, the most common other languages used are C and FORTRAN. As NASA's own software engineers have pointed out, however, C is not a realtime, fault tolerant, distributed, and concurrent programming language, all critical for reliable space system software. Nor is FORTRAN a DBMS language, another important feature. The NASA/industry forum concluded, "We [NASA] have used and are still using these languages [C and FORTRAN] for a kind of software engineering application they were never designed for." State-of-the-art software engineering without Ada is not viable. Support for strong typing, exception handling, packaging, information hiding, and concurrency is necessary to attain that level of engineering discipline.

Status of NASA's Ada Five-Year Plan

NASA's IRM Council expected to have an action plan ready by November 30, 1989, for the agency's Ada transition. Currently, no formal NASA Ada plan or policy (agency wide) has been implemented, despite several NASA studies showing the benefits and critical nature of Ada technology to the space systems software development.

Recommendations

The Ada Software Alliance strongly believes that the lack of formal treatment of software and Ada in the NASA FY91 budget is a critical oversight, and an omission that could severely impact the development and fielding of the Space Station Freedom and other NASA programs. If, in fact, the Ada- and software-related portions of the NASA budget have been "folded into" other portions of the proposed budget, those portions should be restated to explicitly identify the associated software costs.

The transition to Ada by NASA will not be free; in fact, there is a requirement for extensive training, the acquisition of software tools and development computer systems, and for widespread management training and education. The cost of the transition should be identified explicitly in the NASA budget. As NASA's own working group has stated, NASA must establish a means of measuring success in software development. That can only be done by specifying relevant costs and timelines to ensure compliance with the plan and an accomplishment of stated objectives. Those mechanisms are not included in the NASA budget we have reviewed.

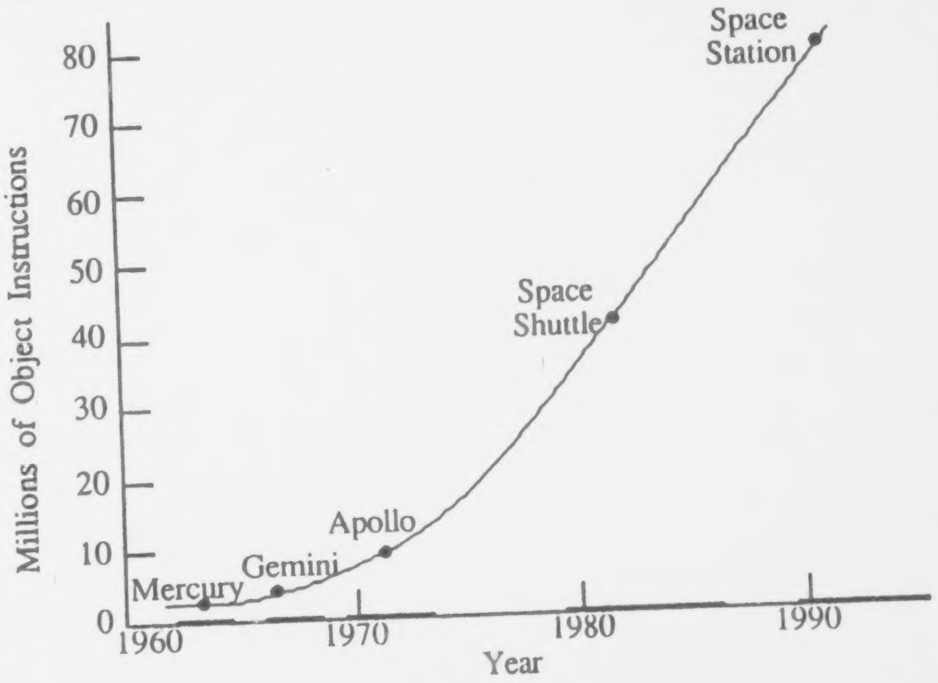
Conclusion

The Ada Software Alliance is strongly supportive of the NASA space programs, and believes the potential benefits of space exploration to this country are enormous. ASA is also cognizant of the critical role of software in the successful implementation of every single NASA program. With software playing such a role, the NASA budget must identify software-related costs, benefits, and schedules, in order to lower risks, ensure visibility of progress, and guard against major setbacks in accomplishing this country's space missions.

Function	Flight/Ground F/G	Size (KSLOC)*	Languages
Flight Planning			
- Design	G	4,700	FORTRAN
- Crew Activity	G	57	FORTRAN
- Remote Manipulation System	G	22	FORTRAN
Flight Readiness			
- S/W** Development Lab	G	1,300	PL/1, HAL, ALC***
- S/W Production Facility	G	2,300	PL/1, C
- Mission Simulation	G	1,800	FORTRAN, ALC
Flight Control			
- Launch Processing	G	13,000	GOAL
- Mission Control	G	1,800	FORTRAN, PL/1
Flight - Onboard	F	580	HAL/S, ALC

* KSLOC = thousands of source lines of code
** S/W = software
*** ALC = assembly language code

Figure 1 — Shuttle Software



Source: Boehm (September 1987).

Figure 2 — Estimated Growth in Software Demand: Manned Spaceflight Program

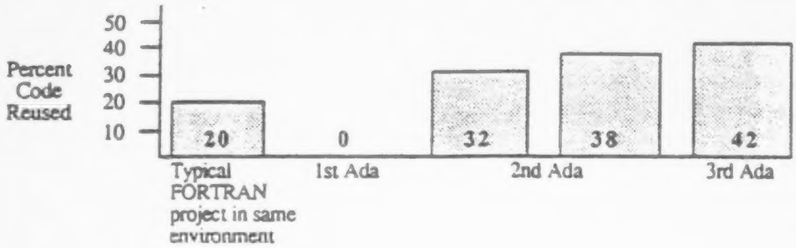


Figure 3 — Reuse trends

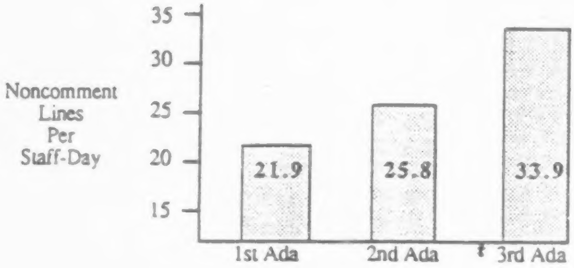


Figure 4 — Productivity Trends

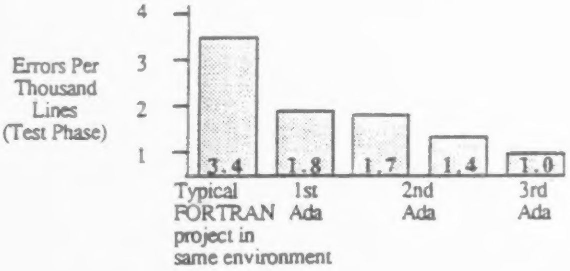


Figure 5 — Error-Rate Trends

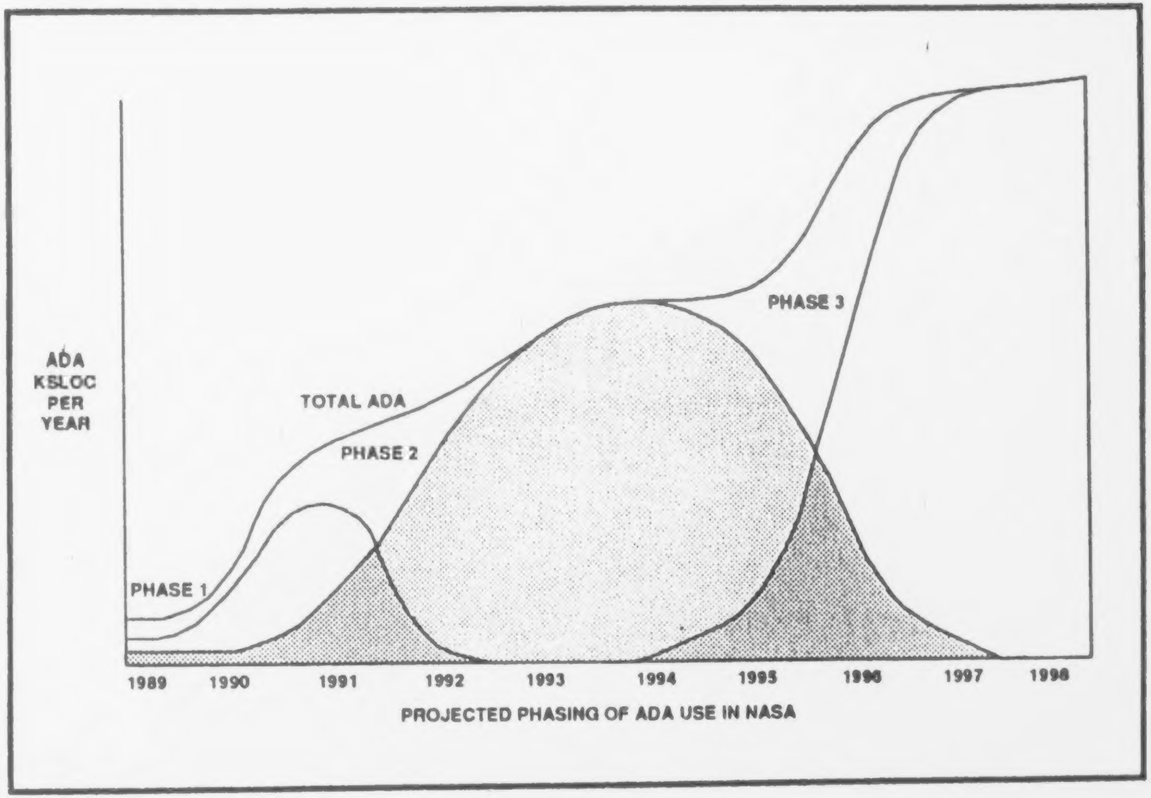


Figure 6 — NASA's Three-phase Ada Transition Plan

STATEMENT OF GEORGE C. SPONSLER, III, CHAIRMAN, IEEE AEROSPACE R&D POLICY COMMITTEE

The Aerospace R&D Policy Committee of the Institute of Electrical and Electronics Engineers' United States Activities Board has reviewed the Administration's civil aerospace policy[1] and proposed 1991 budget. We welcome the President's strong support of the U.S. civil space program and especially the emphasis on advanced technology. The Committee also supports the great majority of the President's space program, but with one exception: what we believe to be NASA's overemphasis of the space station.

Space Station Freedom is represented as "the world's first permanently-manned microgravity and life sciences laboratory. It will eventually have the capability to service satellites in orbit and to serve as a way station on the journey to the moon and Mars."[2] But justifications for the project remain to a certain extent contradictory, intertwined with the need for international leadership and technological prestige.

NASA has proposed that "FY 1991 will be the year that Space Station Freedom makes the critical transition from design to actual fabrication of major long-lead-time hardware."[3] The issue raised is one of cost/benefit: do the projected uses of the space station justify at this time commitment to construction of the presently proposed design, especially in light of its probable total cost?

Historically, the space station's total program cost has grown from an initial estimate of about $8 billion, to $16 billion, to now some $30 billion, with possible future growth on the order of $100 billion, were it actually used as a way-station in the exploration of the moon and Mars. This cost growth may be attributed in part to inflation, but in larger part it reflects drift and delay, both within and outside of NASA, in deciding among the ever changing missions envisioned for the space station. Agreement is lacking in both the technical and political communities as to the particular applications which the space station could best serve, especially in light of overall budgetary restrictions.

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[1] As presented by: National Space Policy, approved by the President on November 2, 1989 and released November 16, 1989; The President's Budget for F.Y. 1991: "Investing in the Future", excerpts Section 1, part III, January 29, 1990; NASA FY 1991 Budget Briefing, January 29, 1990; and Statement of Richard H. Truly, NASA Administrator, January 29, 1990.

[2] President's Budget, op. cit.

[3] Adm. Truly, op. cit., p. 2.

As a general rule, it is unwise to embark on a major program merely because it is technically feasible, or because it makes use of resources which happen to be available and which may serve vested interests. To avoid such criticism in the case of Space Station Freedom it is essential that the needs it will fill be carefully defined and be generally accepted as important and economical. A space station devoted simply to micro-gravity and the life sciences, in our Committee's judgement, does not seem to meet these criteria. Industry has not evinced great interest in zero-gravity manufacturing. And extensive data on human reaction to prolonged zero-gravity is now available from the U.S.S.R.

Probably the best rationale for the space station is as a way-station enroute to the moon and Mars. A space-station could assure the full reusability of all moon-transfer vehicles and perhaps render the flight to Mars more cost effective than it otherwise would be. But the presently planned Space Station Freedom would be too small for such application, even as it is too large simply to serve as an orbiting laboratory. The optimum orbit for a way-station is also undecided, controlled as it is by the radiation threat posed by the Van Allen belt and the restricted altitude capability of the present Shuttle. A low earth-orbit way-station, as presently planned, may prove not to be the preferable approach. Perhaps most important, the White House and Congress would have to accept and budget for the high cost demanded to explore (perhaps even to colonize) the moon and Mars.

We therefore recommend that NASA should continue the space station program in an R&D status at approximately its current $2 billion level of funding, while giving technical assistance to the National Space Council in the investigation and planning of an integrated national space program. Emphasis should be given to the role which a space station should play therein. The integrated national space program we envision would address such basic questions as why we want to be in space, and what specific benefits would be gained by its implementation which would justify the necessarily large costs.

Historically, mankind has crossed the oceans and explored the earth's continents primarily in search of riches and congenial places to live. Do similar considerations govern our future in space; that is, do the need for natural resources, the degradation of our environment, and the exploding earth population dictate our advance into space? Or do international relations, national prestige, and/or economic competitiveness demand our exploration of space? We must determine whether these factors and possibly others guide our destiny in space and provide the needed rationale for our space expenditures.

We do not, however, recommend reduction of the planned total NASA budget but rather its reprogramming to support other applied research and exploratory development needed to define and to develop an integrated space program while simultaneously advancing U.S. industrial competitiveness. Space station R&D funds, for example, should continue for such robotics projects as the $337 million Flight Telerobotic Servicer, which would be used to help astronauts assemble and maintain a possible future space station and which would help the U.S. maintain commercial preeminence in automation systems.

We suggest that NASA, as part of its review, should consider reorienting its R&D into two balanced and complementary programs: Manned Aerospace Transport (MAST); and Automated Satellites and Probes (ASAP). MAST would combine all NASA work on man in both atmosphere and space, including the space station, the shuttles, aviation R&D, and the National Aerospace Plane. High priority would be given to reducing the cost of manned space flight. ASAP would include all earth orbit applications satellites, including ACTS, EOS, Mission to Planet Earth, etc., and all the scientific space probes like Magellan and Cassini.

MAST would concentrate upon developing the most cost-effective approaches to manned exploration of space: addressing the need for the space station, possible use of the shuttle and the space plane as space platforms in lieu of space stations; possible use of the space plane to service a space station or in conjunction with other approaches to send men to the moon and Mars, development of an "Orient Express" or other transoceanic transport, novel aircraft design, and the like.

ASAP would include all earth applications satellites - including communications, navigation, weather, Landsat and other earth observation satellites for environmental and other uses, as well as platforms for solar power and other purposes - in addition to the automated space probes of which NASA and the nation are so justly proud. The space probes would precede and facilitate manned exploration of space; and NASA's automation and robotics R&D would bridge both programs.

The Department of Defense seems eager to transfer total responsibility for the National Aerospace Plane (NASP) to NASA; we strongly recommend that NASA should accept it. We believe that the NASP has great potential and should be given greater immediate emphasis in a reoriented NASA manned space program as successor to the Shuttle. In current proposed Administration plans, the aerospace plane is part of the so-called Moon/Mars Initiative with a proposed 1991 budget of only $277 million, a modest growth from the enacted 1990 budget of $254 million. We suggest the budgeted amount should be doubled, reprogramming the funds presently planned for beginning the fabrication of the space station, which would be postponed.

Part of the augmented NASP R&D funds should be devoted to better defining its proposed uses. In this regard, we believe the NASP should ultimately replace the Shuttle whose utility it would increase, but not be given the Shuttle's present mission of launching satellites, which probably could better be accomplished with unmanned launch vehicles. The NASP could carry cargo and crew to a future space station, help in its construction, or possibly replace it for simpler short-duration missions. It is even possible, though perhaps not cost effective, that the NASP, equipped with a small Lunar Transfer Vehicle (LTV), could be used to ferry men to the moon, much as was done in the original Apollo program. The NASP could also be employed as an "Orient Express" transport for global distances of 10,000 miles or greater.

The NASP program we envision might or might not evolve into two separate planes, as presently planned. We would preserve the space transport version presently proposed, but possibly modify or even abandon the planned Mach 5 hypersonic plane. The "Orient Express" mission would be preserved, but essentially the same version of the NASP would be used as for its space operations (without rocket boosters and probably with different jet fuels). The NASP we envision would employ a somewhat conventional jet engine to take off from a conventional runway, employ ram and scram jets to boost itself into, say, Mach 25 flight at the top of the troposphere, and then use expendable rocket engines to boost it into even higher stratospheric earth orbit. The R&D problems with the engines, flight-control, and materials will require intense industry effort, but should have considerable commercial value and correspondingly enhance our technological competitiveness.

Such R&D would be consonant with NASA's historical mission and make full use of its, and of industry's, capabilities. The NASP would also be timely in that extensions of more conventional aeronautics' R&D may be approaching a technical asymptote in purely atmospheric flight. As attested by the R&D and associated planning for the Navy's Advanced Tactical Aircraft (ATA) and the Air Force's Advanced Tactical Fighter (ATF) the problems posed by high-speed manned flight, particularly at low levels but also at high altitude in the atmosphere, are becoming increasingly difficult to solve at reasonable expense. Except for specific low-level flight requirements, the natural solution is to go beyond the atmosphere, where NASP would fly.

One possible use for an advanced version of NASP would be to construct and maintain a solar power satellite which could convert solar energy into microwave energy that would in turn be transmitted via microwaves to earth where it could supplement and perhaps ultimately partially replace electricity derived from fossil fuel combustion. Such an energy resource would serve to reduce carbon dioxide production resulting from burning such fuels. In turn, this would tend to reduce the so-called greenhouse effect which some believe may threaten worldwide climatic changes. With careful design, solar power planners, such as Gerard K. O'Neill of Princeton and Peter Glaser of A. D. Little, believe the systems could be operated safely and economically.

Such a possibility illustrates how an integrated NASA program could complement both manned and unmanned space operations. The necessary solar cells might be assembled by men in space, or by robots developed through space station R&D, both transported by NASP. The solar cell platform, in a 24 hour stationary orbit, probably would be unmanned during normal operation, but its maintenance might well require human intervention. It might itself even be part of a space station. Integrated technical feasibility and economic planning hold the answers.

Let us turn then to the unmanned program, ASAP. Here NASA's record is as brilliant as its Apollo lunar landings: highlighted by its space probes to Jupiter, Saturn, and Neptune; its pioneering of satellite communications systems; supplemented by its navigation and earth observation systems; and including the wide variety of robot satellites and other probes designed for scientific investigation.

NASA's prior emphasis, during the Reagan administration, on manned space flight and more particularly on the Shuttle was detrimental to its satellite applications and unmanned space-exploration programs in one vital aspect: exclusive reliance upon the Shuttle for all launches significantly increased the launching cost per pound of unmanned vehicles. The Shuttle's own launch delays and the tragic Challenger accident both drastically reduced the frequency of satellite and probe launches. Indeed there were no space probes launched for an entire decade from 1979 through 1988 inclusive. Fortunately that lamentable situation has already been corrected by the Bush administration with the launching of the Magellan and Galileo, and the planned launching of the Hubble Space Telescope this March.

But the launch costs per pound are still exorbitant because of NASA's continued reliance upon the manned Shuttle for all its launches. We strongly recommend development of a family of unmanned, cost-effective booster rockets to overcome this problem. These boosters could be developed commercially, with NASA purchasing launches and helping to defray development costs. What matters is that they be developed quickly and be put into service.

It would be too lengthy to summarize all the various applications satellite programs which do or should exist under NASA auspices. But one in particular has been languishing which offers great promise and which is on the verge of completion: the Advanced Communications Technology Satellite (ACTS).

The ACTS program was begun in 1983 in an effort to regain U.S. leadership in satellite communications. NASA, which had led the world in the field in the 1960s, halted its efforts in the mid-70's when commercial systems were developed. Since then, a number of countries -- Canada, France, Germany, Italy, the U.K., and particularly Japan -- have mounted extensive development programs and have forged ahead of the U.S. in many areas of relevant technology.

The ACTS program, which will have cost the U.S. taxpayers about $500 million over the years, is intended to test and demonstrate a set of advanced technologies needed to make a singularly important stride in satellite communications: a change in basic philosophy in the use of satellites from simply passive channel routers to active processing and communications switching centers in orbit. ACTS' successful demonstration of these technologies will change the very nature of communications satellites, and will position the U.S. to retain its present, and hopefully gain an ever-growing future portion of the $5 billion annual satellite communications market.

But NASA does not appear prepared to exploit operationally the anticipated success of the ACTS program. Indeed, NASA has been perceived historically as not even supporting ACTS. Since the program's inception in 1983, until this year, OMB has deleted the requested funding for ACTS from the NASA budget; but fortunately, each year the Congress has restored it. One particularly adverse effect of this history is that NASA has inadequately planned for the test and demonstration period following the launch of ACTS. This deficiency is in spite of NASA's unprecedentedly successful experiences planning and executing long-duration demonstration experiments with public participation on the ATS-6 and CTS programs in the mid 1970's. But today there are no adequate plans to test ACTS' performance in orbit or to demonstrate its ability to provide advanced and specialized services. The envisoned ground complex of terminals and user equipments is completely inadequate to properly test, calibrate, and demonstrate the ACTS system.

And so we are led full circle: what is demanded is agreement between NASA, the Space Council and the Congress as to what our nation's space programs should be. Just as Space Station Freedom needs a consensus to guide its possible future development, so too does ACTS need broad acceptance in order to reap its potential benefits. The United States must first justify, prioritize, and select its aerospace programs, both manned and unmanned, if our nation is to maintain its lead in aeronautics and space R&D. Our future aerospace success demands agreement and cooperation on objectives and budgets between Congress and the White House.